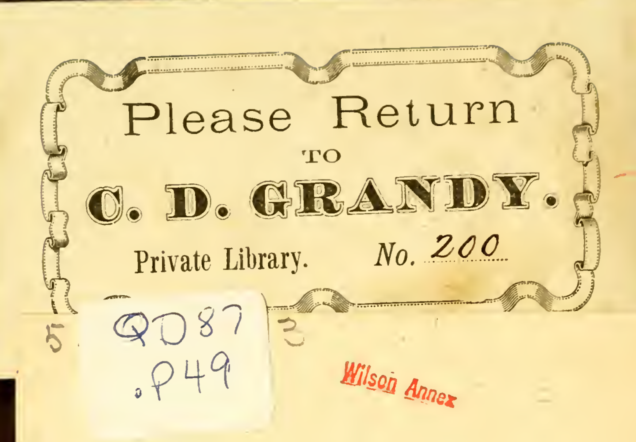
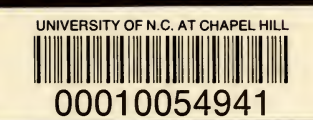
GUIDE TO USE

OF THE

BLOW-PIPE.

PLYMPTON.


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THE

BLOWPIPE;

A

GUIDE TO ITS USE

IN THE

DETERMINATION OF SALTS AND MINERALS.

COMPILED FROM VARIOUS SOURCES BY

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PREFACE.

The following pages have been compiled from such available material as seemed best adapted to the needs of the beginner in the use of the blowpipe.

Parts I and II have been adapted with but few emendations from the work of Sheerer and Blanford. The alterations have chiefly been in the chemical symbols, the new nomenclature replacing the old.

Part III is translated from "Guide Pratique pour la Détermination des Minéraux," par Aug. Guerout; the original was written by Dr. Fuchs of Heidelberg. In place of the complex chemical formulas of the French and German works, I have, in consequence of the elementary character of the book, preferred to give the chemical names.

As a convenient guide to the learner, this compilation is offered to scientific students.

Geo. W. Plympton.

Polytechnic Institute,
Brooklyn, *July, 1874.*

THE BLOWPIPE.

Part First.

THE USE OF THE BLOWPIPE.

Perhaps during the last fifty years, no department of chemistry has been so enriched as that relating to analysis by means of the Blowpipe.

Through the unwearied exertions of men of science, the use of this instrument has arrived to such a degree of perfection, that we have a right to term its use, "Analysis in the *dry* way," in contradistinction to analysis "in the *wet* way." The manipulations are so simple and expeditious, and the results so clear and characteristic, that the Blowpipe analysis not only verifies and completes the results of analysis in the wet way, but it gives in many cases direct evidences of the presence or absence of many substances, which would not be otherwise detected, but through a troublesome and tedious process, involving both prolixity and time; for instance, the detection of manganese in minerals.

Many substances have to go through Blowpipe manipulations before they can be submitted to an analysis in the wet way.

The apparatus and reagents employed are compendious and small in number, so that they can be carried easily while on scientific excursions, a considerable advantage for mineralogists and metallurgists.

The principal operations with the Blowpipe may be explained briefly as follows :

(*a.*) By *Ignition* is meant the exposure of a substance to such a degree of heat, that it glows or emits light, or becomes red-hot. Its greatest value is in the separation of a volatile substance from one less volatile, or one which is entirely fixed at the temperature of the flame. In this case we only take cognizance of the latter or fixed substance, although in many instances we make use of ignition for the purpose of changing the conditions of a substance, for example, the sesqui-oxide of chromium (Cr^2O^3) in its insoluble modification ; and as a preliminary examination for the purpose of ascertaining whether the subject of inquiry be a combination of an organic or inorganic nature.

The apparatus used for this purpose are crucibles of platinum or silver, platinum foil, a platinum spoon, platinum wire or tongs, charcoal, glass tubes, and iron spoons.

(*b.*) *Sublimation* is that process by which we convert a solid substance into vapor by means of a strong heat. These vapors are condensed by refrigeration into the solid form. It may be termed a distillation of a solid substance. Sublimation is of great consequence in the detection of many substances ; for nstance, arsenic, antimony, mercury, etc.

The apparatus used for the purposes of sublimation consist of glass tubes closed at one end.

(*c.*) *Fusion.*—Many substances when exposed to a certain degree of heat lose their solid form, and are converted into a liquid. Those substances which do not become converted into the liquid state by heat, are said to be infusible. It is a convenient classification to arrange substances into those which are fusible with difficulty, and those which are easily fusible. Very often we resort to fusion for the purpose of decomposing a

substance, or to cause it to enter into other combinations, by which means it is the more readily detected. If insoluble substances are fused with others more fusible (reagents) for the purpose of causing a combination which is soluble in water and acids, the operation is termed *unclosing*. These substances are particularly the silicates and the sulphates of the alkaline earths. The usual reagents resorted to for this purpose are carbonate of soda (Na_2CO_3), carbonate of potash (K_2CO_3), or still better, a mixture of the two in equal parts. In some cases we use the hydrate of barytes [$Ba(HO)_2$] and the bisulphate of potash ($KHSO_4$). The platinum spoon is generally used for this manipulation.

Substances are exposed to fusion for the purpose of getting a new combination which has such distinctive characteristics that we can class it under a certain group; or for the purpose of ascertaining at once what the substance may be. The re-agents used for this purpose are borax [$NaH(BO_2)_2$] and the microcosmic salt (Na, NH_4, HPO_4). Charcoal and the platinum wire are used as supports for this kind of operation.

(*d.*) *Oxidation.*—The chemical combination of any substance with oxygen is termed *oxidation*, and the products are termed *oxides*. As these oxides have qualities differing from those which are non-oxidized, it therefore frequently becomes necessary to convert substances into oxides; or, if they are such, of a lower degree, to convert them into a higher degree of oxidation. These different states of oxidation frequently present characteristic marks of identity sufficient to enable us to draw conclusions in relation to the substance under examination. For instance, the oxidation of manganese, of arsenic, etc. The conditions necessary for oxidation, are high temperature and the free admission of air to the substance.

If the oxidation is effected through the addition of a substance containing oxygen (for instance, the nitrate or chlorate of potash) and the heating is accompanied by a lively deflagration and crackling noise, it is termed *detonation*. By this

process we frequently effect the oxidation of a substance, and thus we prove the presence or the absence of a certain class of substances. For instance, if we detonate (as it is termed by the German chemists) the sulphide of antimony, or the sulphide of arsenic with nitrate of potash, we get the nitrate of antimony, or the nitrate of arsenic. The salts of nitric or chloric acid are determined by fusing them with the cyanide of potassium, because the salts of these acids detonate.

(*e.*) *Reduction.*—If we deprive an oxidized substance of its oxygen, we term the process *reduction.* This is effected by fusing the substance under examination with another which possesses a greater affinity for oxygen. The agents used for reduction are hydrogen, charcoal, soda, cyanide of potassium, etc. Substances generally, when in the unoxidized state, have such characteristic qualities, that they cannot very readily be mistaken for others. For this reason, reduction is a very excellent expedient for the purpose of discerning and classifying many substances.

B. UTENSILS.

We shall give here a brief description of the most necessary apparatus used for analysis in the dry way, and of their use.

The Blowpipe is a small instrument, made generally out of brass, silver, or German silver, and was principally used in earlier times for the purpose of soldering small pieces of metals together. It is generally made in the form of a tube, bent at a right angle, but without a sharp corner. The largest one is about seven inches long, and the smallest about two inches. The latter one terminates with a small point, with a small orifice. The first use of the blowpipe that we have recorded is that of a Swedish mining officer, who used it in the year 1738 for chemical purposes, but we have the most meagre accounts of his operations. In 1758 another Swedish mining officer, by the name of Cronstedt, published his "Use of the Blowpipe in

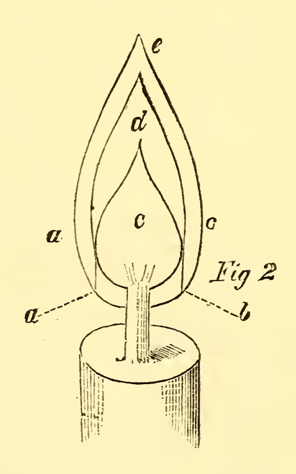
Chemistry and Mineralogy," translated into English, in 1770, by Van Engestroem. Bergman extended its use, and after him Ghan and the venerable Berzelius (1821). The blowpipe most generally used in chemical examinations is composed of the following parts: (*Fig.* 1.) A is a little reservoir made air-tight by grinding the part B into it. This reservoir serves the purpose of retaining the moisture with which the air from the mouth is charged. A small conical tube is fitted to this reservoir. This tube terminates in a fine orifice. As this small point is liable to get clogged up with soot, etc., it is better that it should be made of platinum, so that it may be ignited. Two of these platinum tubes should be supplied, differing in the size of the orifice, by which a stronger or lighter current of flame may be projected from it. Metals, such as brass or German silver, are very liable to become dirty through oxidation, and when placed between the lips are liable to impart a disagreeable taste. To avoid this, the top of the tube must be supplied with a mouthpiece of ivory or horn C. The blowpipe here represented is the one used by Ghan, and approved by Berzelius. The trumpet mouthpiece was adopted by Plattner; it is pressed upon the lips while blowing, which is less tiresome than holding the mouthpiece between the lips, although many prefer the latter mode.

Dr. Black's blowpipe is as good an instrument and cheaper.

It consists of two tubes, soldered at a right angle ; the larger one, into which the air is blown, is of sufficient capacity to serve as a reservoir.

A chemist can, with a blowpipe and a piece of charcoal, determine many substances without any reagents, thus enabling him, even when travelling, to make useful investigations with means which are always at his disposal. There are pocket blowpipes as portable as a pencil case, such as Wollaston's and Mitscherlich's ; these are objectionable for continued use as their construction requires the use of a metallic mouthpiece. Mr. Casamajor, of New York, has made one lately which has an ivory mouthpiece, and which, when in use, is like Dr. Black's.

The length of the blowpipe is generally seven or eight inches, but this depends very much upon the visual angle of



the operators. A short-sighted person, of course, would

require an instrument of less length than would suit a far-sighted person.

The purpose required of the blowpipe is to introduce a fine current of air into the flame of a candle or lamp, by which a higher degree of heat is induced, and consequently combustion is more rapidly accomplished.

By inspecting the flame of a candle burning under usual circumstances, we perceive at the bottom of the flame a portion which is of a light blue color (*a b*), *Fig.* 2, which gradually diminishes in size as it recedes from the wick, and disappears when it reaches the perpendicular side of the flame. In the midst of the flame there is a dark nucleus with a conical form (*c*). This is enveloped by the illuminating portion of the flame (*d*). At the exterior edge of the part *d* we perceive a thin, scarcely visible veil, *a*, *e*, *c*, which is broader near the apex of the flame. The action of the burning candle may be thus explained. The radiant heat from the flame melts the tallow or wax, which then passes up into the texture of the wick by capillary attraction until it reaches the glowing wick, where the heat decomposes the combustible matter into carburetted hydrogen (C^2H^4), and into carbonic oxide (CO).

While these gases are rising in hot condition, the air comes in contact with them and effects their combustion. The dark portion, *c*, of the flame is where the carbon and gases have not a sufficiency of air for their thorough combustion; but gradually they become mixed with air, although not then sufficient for complete combustion. The hydrogen is first oxidized or burnt, and then the carbon is attacked by the air, although particles of carbon are separated, and it is these, in a state of intense ignition, which produce the illumination. By bringing any oxidizable substance into this portion of the flame, it oxidizes very quickly in consequence of the high temperature and the free access of air. For that reason this part of the flame is termed the oxidizing flame, while the illuminating portion, by its tendency to abstract oxygen for the purpose of complete combustion, easily reduces oxidized substances

brought into it, and it is, therefore, called the flame of reduction. In the oxidizing flame, on the contrary, all the carbon which exists in the interior of the flame is oxidized into carbonic acid (CO^2) and carbonic oxide (CO), while the blue color of the cone of the flame is caused by the complete combustion of the carbonic oxide. These two portions of the flame—the oxidizing and the reducing—are the principal agents of blowpipe analysis.

If we introduce a fine current of air into a flame, we notice the following: The air strikes first the dark nucleus, and forcing the gases beyond it, mixes with them, by which oxygen is mingled freely with them. This effects the complete combustion of the gases at a certain distance from the point of the blowpipe. At this place the flame has the highest temperature, forming there the point of a blue cone. The illuminated or reducing portion of the flame is enveloped outside and inside by a very hot flame, whereby its own temperature is so much increased that in this reduction-flame many substances will undergo fusion which would prove perfectly refractory in a common flame. The exterior scarcely visible part loses its form, is diminished, and pressed more to a point, by which its heating power is greatly increased.

The Blast of Air.—By using the blowpipe for chemical purposes, the effect intended to be produced is an uninterrupted steady stream of air for many minutes together, if necessary, without an instant's cessation. Therefore, the blowing can only be effected with the muscles of the cheeks, and not by the exertion of the lungs. It is only by this means that a steady constant stream of air can be kept up, while the lungs will not be injured by the deprival of air. The details of the proper manner of using the blowpipe are really more difficult to describe than to acquire by practice; therefore the pupil is requested to apply himself at once to its practice, by which he will soon learn to produce a steady current of air, and to distinguish the different flames from each other. We would simply say that the tongue must be applied to the roof of the

mouth, so as to interrupt the communication between the passage of the nostrils and the mouth. The operator now fills his mouth with air, which is to be passed through the pipe by compressing the muscles of the cheeks, while he breathes through the nostrils, and uses the palate as a valve. When the mouth becomes nearly empty, it is replenished by the lungs in an instant, while the tongue is momentarily withdrawn from the roof of the mouth. The stream of air can be continued for a long time, without the least fatigue or injury to the lungs. The easiest way for the student to accustom himself to the use of the blowpipe, is first to learn to fill the mouth with air, and while the lips are kept firmly closed to breathe freely through the nostrils. Having effected this much, he may introduce the mouthpiece of the blowpipe between his lips. By inflating the cheeks, and breathing through the nostrils, he will soon learn to use the instrument without the least fatigue. The air is forced through the tube against the flame by the action of the muscles of the cheeks, while he continues to breathe without interruption through the nostrils. Having become acquainted with this process, it only requires some practice to produce a steady jet of flame. A defect in the nature of the combustible used, as bad oil, such as fish oil, or oil thickened by long standing or by dirt, dirty cotton wick, or an untrimmed one, or a dirty wickholder, or a want of steadiness of the hand that holds the blowpipe, will prevent a steady jet of flame. But frequently the fault lies in the orifice of the jet, or too small a hole, or its partial stoppage by dirt, which will prevent a steady jet of air, and lead to difficulty. With a good blowpipe the air projects the entire flame, forming a horizontal, blue cone of flame, which converges to a point at about an inch from the wick, with a larger, longer, and more luminous flame enveloping it, and terminating to a point beyond that of the blue flame.

To produce an efficient flame of oxidation, put the point of the blowpipe into the flame about one third the diameter of the wick, and about one twelfth of an inch above it. This,

however, depends upon the size of the flame used. Blow strong enough to keep the flame straight and horizontal, using the largest orifice for the purpose. Upon examining the flame thus produced, we will observe a long, blue flame, *a b*, Fig. 3, which letters correspond with the same letters in Fig. 2. But this flame has changed its form, and contains all the combustible gases. It forms now a thin, blue cone, which converges to a point about an inch from the wick. This point of the

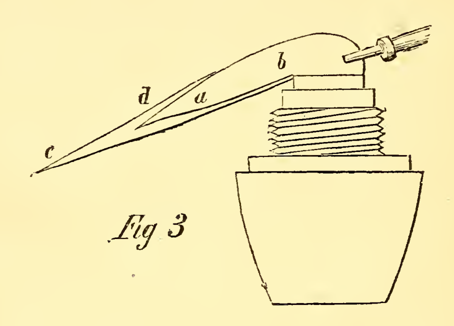


Fig 3

flame possesses the highest intensity of temperature, for there the combustion of the gases is the most complete. In the original flame, the hottest part forms the external envelope, but here it is compressed more into a point, forming the cone of the blue flame, and likewise an envelope of flame surrounding the blue one, extending beyond it from *a* to *c*, and presenting a light bluish or brownish color. The external flame has the highest temperature at *d*, but this decreases from *d* to *c*.

If there is a very high temperature, the oxidation is not effected so readily in many cases, unless the substance is removed a little from the flame; but if the heat be not too high, it is readily oxidized in the flame, or near its cone. If the current

of air is blown too freely or violently into the flame, more air is forced there than is sufficient to consume the gases. This superfluous air only acts detrimentally, by cooling the flame.

In general the operation proceeds best when the substance is kept at a dull red heat. The blue cone must be kept free from straggling rays of the yellow or reduction flame. If the analysis be effected on charcoal, the blast should not be too strong, as a part of the coal would be converted into carbonic oxide, which would act antagonistically to the oxidation. The oxidation flame requires a steady current of air, for the purpose of keeping the blue cone constantly of the same length. For the purpose of acquiring practice, the following may be done: Melt a little molybdic acid with some borax, upon a platinum wire, about the sixteenth of an inch from the point of the blue cone. In the pure oxidation flame, a clear yellowish glass is formed; but as soon as the reduction flame reaches it, or the point of the blue cone touches it, the color of the bead changes to a brown, which, finally, after a little longer blowing, becomes quite dark, and loses its transparency. The cause of this is, that the molybdic acid is very easily reduced to a lower degree of oxidation, or to the oxide of molybdenum. The flame of oxidation will again convert this oxide into the acid, and this conversion is a good test of the progress of the student in the use of the blowpipe. In cases where we have to separate a more oxidizable substance from a less one, we use with success the blue cone, particularly if we wish to determine whether a substance has the quality, when submitted to heat in the blue cone, of coloring the external flame.

A good *reduction* flame can be obtained by the use of a small orifice at the point of the blowpipe. In order to produce such a flame, hold the point of the blowpipe higher above the wick, while the nozzle must not enter the flame so far as in the production of the oxidation flame. The point of the blowpipe should only touch the flame, while the current of air blown into it must be stronger than into the oxidation flame. If we project a stream, in the manner mentioned, into the flame, from

the smaller side of the wick to the middle, we shall perceive the flame changed to a long, narrow, luminous cone, *a b*, Fig. 4,

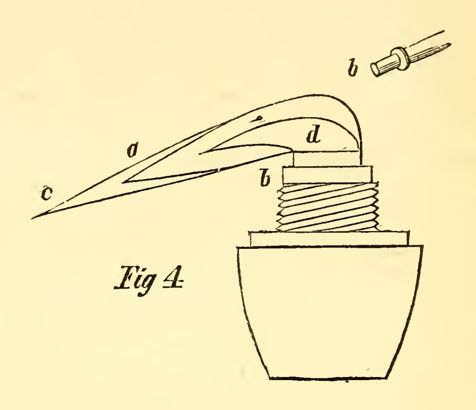


Fig 4

the end *a* of which is enveloped by the same dimly visible blueish colored portion of the flame *a, c*, which we perceive in the original flame, with its point at *c*. The portion close above the wick, presenting the dull appearance, is occasioned by the rising gases which have not supplied to them enough oxygen to consume them entirely. The hydrogen is consumed, while the carbon is separated in a state of bright ignition, and forms the internal flame.

Directly above the wick, the combustion of the gases is least complete, and forms there likewise, as is the case in the free flame, a dark blue nucleus *d*.

If the oxide of a metal is brought into the luminous portion of the flame produced as above, so that the flame envelopes the substance perfectly, the access of air is prevented. The partially consumed gases have now a strong affinity for oxygen, under the influence of the intense heat of that part of the flame. The substance is thus deprived of a part, or the whole, of its oxygen, and becomes *reduced* according to the strength of the affin-

ity which the substance itself has for oxygen. If the reduction of a substance is undertaken on platinum, by fusion with a flux, and if the oxide is difficult to reduce, the reduction will be completely effected only in the luminous part of the flame. But if a substance be reduced on charcoal, the reduction will take place in the blue part of the flame, as long as the access of air is cut off; but it is the luminous part of the flame which really possesses the greatest reducing power.

The following should be observed in order to procure a good reduction flame:

The wick should not be too long, that it may make a smoke, nor too short, otherwise the flame will be too small to produce a heat strong enough for reduction.

The wick must be free from all loose threads, and from charcoal.

The blast should be continued for a considerable time without intermission, otherwise reduction cannot be effected.

For the purpose of acquiring practice, the student may fuse the oxide of manganese with borax, upon a platinum wire, in the oxidation flame, when a violet-red glass will be obtained; or if too much of the oxide be used, a glass of a dark color and opaque will be obtained. By submitting this glass to the reduction flame, it will become colorless in correspondence to the perfection with which the flame is produced. Or a piece of tin may be fused upon charcoal, and kept in that state for a considerable time, while it presents the appearance of a bright metal on the surface. This will require dexterity in the operator; for, if the oxidation flame should chance to touch the bright metal only for a moment, it is coated with an infusible oxide.

COMBUSTION.—Any flame of sufficient size can be used for blowpipe operations. It may be either the flame of a candle of tallow or wax, or the flame of a lamp. The flame of a wax candle, or of an oil lamp is most generally used. Sometimes a lamp is used filled with a solution of spirits of turpentine in strong alcohol. If a candle is used, it is well to cut the wick

off short, and to bend the wick a little toward the substance experimented upon. But candles are not the best for blowpipe operations, as the radiant heat, reflecting from the substance upon the wax or tallow, will cause it to melt and run down the side of the candle; while again, candles do not give heat enough. The lamp is much the most desirable. The subjoined figure, from Berzelius, is perhaps the best form of lamp. It is

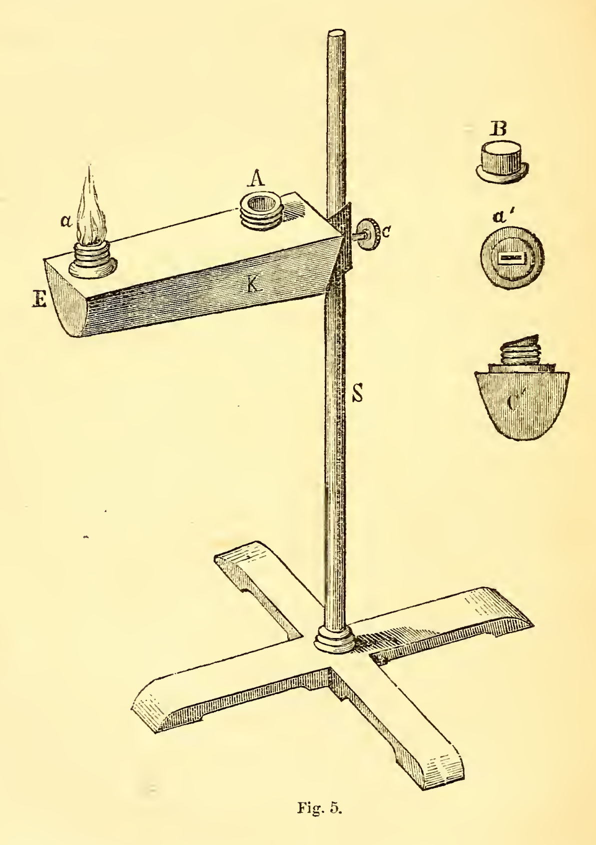


Fig. 5.

made of japanned tin-plate, about four inches in length, and has

the form and arrangement represented in Fig. 5. K is the lamp, fastened on the stand, S, by a screw, C, and is movable upwards or downwards, as represented in the figure. The posterior end of the lamp may be about one inch square, and at its anterior end, E, about three-quarters of an inch square. The under side of this box may be round, as seen in the figure. The oil is poured into the orifice, A, which has a cap screwed over it. C′ is a wick-holder for a flat lamp-wick. *a* is a socket containing the wick, which, when not in use, is secured from dirt by the cap. The figures B and *a′* give the forms of the cap and socket. The best combustible for this lamp is the refined rape-seed oil, or pure sweet oil. When this lamp is in use, there must be no loose threads, or no charcoal on the wick, or these will produce a smoky flame. The wick, likewise, should not be pulled up too high, as the same smoky flame would be produced.

The Spirit-Lamp.—This is a short, strong glass lamp, with a cap, B, Fig. 6, fitted to it by grinding, to prevent the eva-

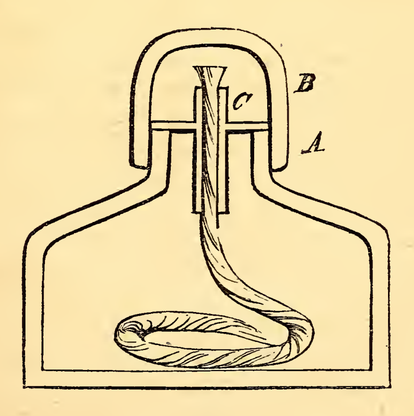


Fig. 6.

poration of the alcohol. The neck *a* contains a tube C, made of silver, or of tin plate, and which contains the wick. Brass

would not answer so well for this tube, as the spirits would oxidize it, and thus impart color to the flame. The wickholder must cover the edge of the neck, but not fit tight within the tube, otherwise, by its expansion, it will break the glass. It is not necessary that alcohol, very highly rectified, should be burnt in this lamp, although if too much diluted with water, enough heat will not be given out. Alcohol of specific gravity 0.84 to 0.86 is the best.

This lamp is generally resorted to by blowpipe analysts, for the purpose of experiments in glass apparatus, as the oily combustibles will coat the glass with soot. Some substances, when exposed to the dark part of the flame, become reduced and, *in statu nascendi*, evaporated ; but by passing through the external part of the flame, they become oxidized again, and impart a color to the flame. The spirit flame is the most efficient one for the examination of substances the nature of which we wish to ascertain through color imparted to the flame, as that of the spirit-lamp being colorless, is, consequently, most easily and thoroughly recognized by the slightest tinge imparted to it.

It is necessary that in operating with such minute quantities of substances as are used in blowpipe analysis, that they should have some appropriate support. In order that no false results may ensue, it is necessary that the supports should be of such a nature that they will not form a chemical combination with the substance while it is exposed to fusion or ignition. Appropriate supports for the different blowpipe experiments are charcoal, platinum instruments, and glass tubes.

(*a.*) *Charcoal.*—The value of charcoal as a support may be stated as follows :

1. The charcoal is infusible, and being a poor conductor of heat, a substance can be exposed to a higher degree of heat upon it than upon any other substance.

2. It is very porous, and therefore allows easily fusible substances (such as alkalies and fluxes) to pass into it, while other substances less fusible, such as metals, to remain unabsorbed.

3. It has likewise a great reducing power.

The best kind of charcoal is that of pinewood, linden, willow, or alderwood, or any other soft wood. Coal from the firwood sparkles too freely, while that of the hard woods contains too much iron in its ashes. Smooth pieces, free from bark and knots, should be selected. It should be thoroughly burnt, and the annual rings or growths should be as close together as possible.

If the charcoal is in masses, it should be sawed into pieces about six inches in length by about two inches broad, but so that the year-growths run perpendicular to the broadest side, as the other sides, by their unequal structure, burn unevenly.

That the substance under examination may not be carried off by the blast, small conical concavities should be cut in the broad side of the charcoal, between the year-growths, with a conical tube of tin plate about two or three inches long, and one quarter of an inch at one end, and half an inch at the other. These edges are made sharp with a file. The widest end of this charcoal borer is used for the purpose of making cavities for cupellation.

In places where the proper kind of charcoal is difficult to procure, it is economical to cut common charcoal into pieces about an inch broad, and the third of an inch thick. In each of these little pieces small cavities should be cut with the small end of the borer. When these pieces of charcoal are required for use, they must be fastened to a narrow slip of tin plate, one end of which is bent into the form of a hook, under which the plate of charcoal is pushed.

In general, we use the charcoal support where we wish to reduce metallic oxides, to prevent oxidation, or to test the fusibility of a substance. There is another point to which we would direct the student. Those metals which are volatile in the reduction flame, appear as oxides in the oxidation flame. These oxides make sublimates upon the charcoal close in the vicinity of the substance, or where it rested, and by their peculiar color indicate pretty correctly the species of minerals experimented upon.

(*b.*) *Platinum Supports.*—The metal platinum is infusible in the blowpipe flame, and is such a poor conductor of heat that a strip of it may be held close to that portion of it which is red hot without the least inconvenience to the fingers. It is necessary that the student should be cognizant of those substances which would not be appropriate to experiment upon if placed on platinum. Metals should not be treated upon platinum apparatus, nor should the easily reducible oxides, sulphides, nor chlorides, as these substances will combine with the platinum, and thus render it unfit for further use in analysis.

(*c.*) *Platinum Wire.*—As the color of the flame cannot be well discerned when the substance is supported upon charcoal, in consequence of the latter furnishing false colors, by its own reflection, to the substances under examination, we use platinum wire for that purpose, when we wish to examine those substances which give indications by the peculiar color which they impart to fluxes. The wire should be about as thick as No. 16 or 18 wire, or about 0.4 millimetre, and cut into pieces about from two and a half to three inches in length. The end of each piece is crooked. In order that these pieces should remain clear of dirt, and ready for use, they should be kept in a glass of water. To use them, we dip the wetted hooked end into the powdered flux (borax or microcosmic salt) some of which will adhere, when we fuse it in the flame of the blowpipe to a bead. This bead hanging in the hook, must be clear and colorless. Should there not adhere a sufficient quantity of the flux in the first trial to form a bead sufficiently large, the hook must be dipped a second time in the flux and again submitted to the blowpipe flame. To fix the substance to be examined to the bead, it is necessary, while the latter is hot, to dip it in the powdered substance. If the hook is cold, we moisten the powder a little, and then dip the hook into it, and then expose it to the oxidation flame, by keeping it exposed to a regular blast until the substance and the flux are fused together, and no further alteration is produced by the flame.

The platinum wire can be used except where reduction to the metallic state is required. Every reduction and oxidation experiment, if the results are to be known by the color of the fluxes, should be effected upon platinum wire. At the termination of the experiment or investigation, if it be one, to clean the wire, place it in water, which will dissolve the bead.

(*d.*) *Platinum Foil.*—For the heating or fusing of a substance, whereby its reduction would be avoided, we use platinum foil as a support. This foil should be of the thickness of good writing paper, and from two and a half to three inches long, by about half an inch broad, and as even and smooth as possible. If it should become injured by long use, cut the injured end off, and if it should prove too short to be held with the fingers, a pair of forceps may be used to grasp it, or it may be placed on a piece of charcoal

(*e.*) *Platinum Spoon.*—When we require to fuse substances with the acid sulphate of potash, or to oxidize them by detonation with nitrate of potash, whereby we wish to preserve the oxide produced, we generally use a little spoon of platinum, about from nine to fifteen millimetres * in diameter, and shaped as represented in Fig. 7. The handle of this spoon is

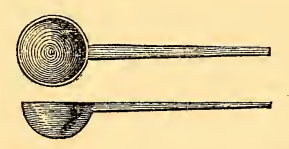


Fig. 7.

likewise of platinum, and should fit into a piece of cork, or be held with the forceps.

(*f.*) *Platinum Forceps or Tongs.*—We frequently are necessitated to examine small splinters of metals or minerals directly in the blowpipe flame. These pieces of metallic substances are held with the forceps or tongs represented as in

* The French millimetre is about the twenty-fifth part of an English inch.

Fig. 8, where *a c* is formed of steel, and *a a* are platinum



Fig. 8.

bars inserted between the steel plates. At *b b* are knobs which by pressure so separate the platinum bars *a a*, that any small substance can be inserted between them.

(*g.*) *Iron Spoons.*—For a preliminary examination iron spoons are desirable. They may be made of sheet iron, about one-third of an inch in diameter, and are very useful in many examinations where the use of platinum would not be desirable.

(*h.*) *Glass Tubes.*—For the separation and recognition of volatile substances before the blowpipe flame, we use glass tubes. These should be about one-eighth of an inch in diameter, and cut into pieces about five or six inches in length. These tubes should have both ends open.

Tubes are of great value in the examination of volatile substances which require oxidizing or roasting, and heating with free access of air. Also to ascertain whether a substance under examination will sublimate volatile matter of a certain appearance. Such substances are selenium, sulphur, arsenic, antimony, and tellurium. These substances condense on a cool part of the tube, and they present characteristic appearances, or they may be recognized by their peculiar smell. These tubes must be made of the best kind of glass, white and difficult of fusion, and entirely free from lead. The substance to be examined must be put in the tube near one end, and exposed to the flame of the blowpipe. The end containing the substance must be held lower than the other end, and must be moved a little over the spirit-lamp before a draught of air is produced through the tube. It is a good plan to have a number

of these tubes on hand. After having used a tube we cut off that end of it which contained the substance, with a file, and clean it from the sublimate, either by heating it over the spirit-lamp, or with a piece of paper wound around a wire. It sometimes happens that the substance falls out of the tube

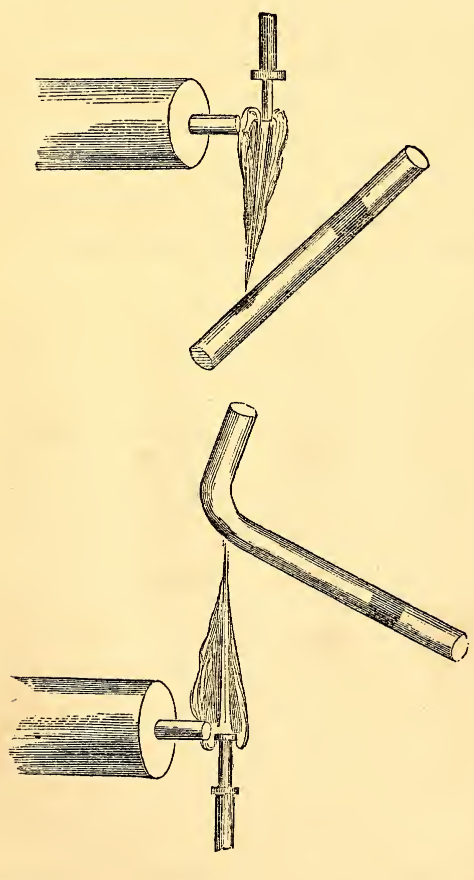


Fig. 9.

before it becomes sufficiently melted to adhere to the glass. To obviate this, we bend the tube not far from the end, at an obtuse angle, and place the substance in the angle, whereby the tube may be lowered as much as necessary. Fig. 9 will give the student a comprehension of the processes described, and of the manner of bending the tubes.

(*i.*) *Glass Tubes closed at one End.*—If we wish to expose volatile substances to heat, with the exclusion of air as much as possible, or to ascertain the contents of water, or other volatile fluids, or for the purpose of heating substances which will decrepitate, we use glass tubes closed at one end. These tubes must be about one-eighth of an inch wide, and from two to three inches in length. They should be made of white glass, difficult of fusion, and free from lead. They should be closed at one end, as figured in the margin, Fig. 10.

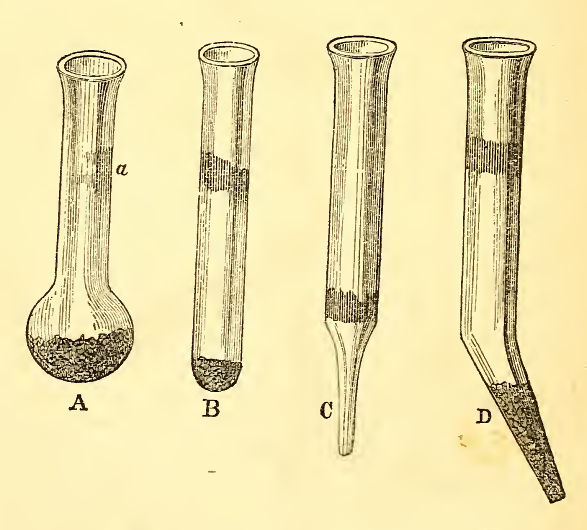


Fig. 10.

When a substance is to be examined for the purpose of

ascertaining whether it contains combustible matter, as sulphur or arsenic, and where we wish to avoid oxidation, we use these tubes without extending the closed end, in order that there may be as little air admitted as possible, as is represented in tube B. But when a substance to be examined is to be tested for water, or other incombustible volatile matters, we employ tubes with little bulbs blown at one end, such as represented at tube A. Here there is room for a circulation of air at the bottom of the tube, by which the volatile matter rises more easily. In some cases, it is necessary to draw the closed end out to a fine point, as in the tubes C and D. Either one or the other of these tubes is employed, depending upon the nature of the substance used. The sublimates condense at the upper part of the tube *a*, and can be there examined and recognized. These tubes, before being used, must be thoroughly dried and cleaned. In experimenting with them, they should not be exposed at once to the hottest part of the flame, but should be submitted to the heat gradually. If the substance is of such a nature that it will sublime at a low heat, the tube should be held more horizontal, while a higher heat is attained by bringing the tube to a more vertical position.

VARIOUS APPARATUS NECESSARY.

Edulcorator or Washing Bottle.—Take a glass bottle of the capacity of about twelve ounces, and close the mouth of it very tight with a cork, through which a short glass tube is fitted airtight. The external end of this tube is drawn out to a point, with a very fine orifice. The bottle should be filled about half full of water. By blowing air into the bottle through the tube, and then turning it downwards, the compressed air will expel a fine stream of water through the fine orifice with considerable force. We use this washing bottle, Fig. 11, for the purpose of rinsing the small particles of coal from the reduced metals.

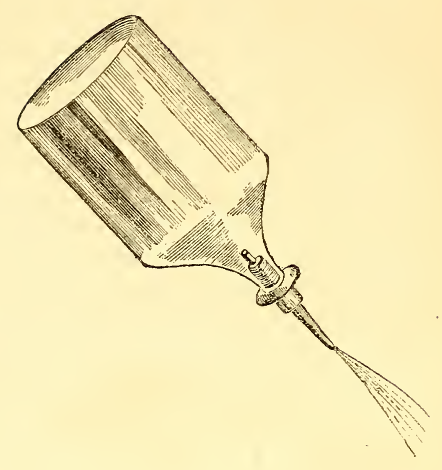


Fig. 11.

Agate Mortar and Pestle.—This mortar is used for the purpose of pulverizing hard substances, and for mixing fluxes. As this mortar will not yield to abrasion, there is no danger of any foreign matter becoming mixed with the substance pulverized in it. It should be cleaned after use with pumice stone. Steel mortars are very useful for the pulverization of hard bodies ; but for all those substances which require great care in their analysis, and which can be obtained in very minute quantity, the agate mortar alone should be used.

A *hammer* made of steel is necessary. This should have the edge square.

A small *anvil*, polished on the surface, is also required. It is frequently used to test the malleability of metals.

A *knife*, for the purpose of ascertaining the hardness of minerals.

The student should also be provided with several three-edged files, and likewise with some flat ones.

A *microscope*, an instrument with two lenses, or with such a combination of lenses, that they may be used double or single,

is frequently necessary for the examination of blowpipe experiments, or the reaction of the fluxes. Common lenses, howsoever cheap they may be, are certainly not recommended. A microscope with achromatic lenses can now be purchased so cheap that there is no longer any necessity of procuring one with the common lens. Besides, there is no reliability whatever to be placed in the revelations of the common lens ; while on the contrary, the deceptive appearances which minute objects assume beneath such lenses are more injurious than otherwise. A small cheap set of magnifying glasses are all that is required for the purpose of blowpipe analysis, Fig. 12.

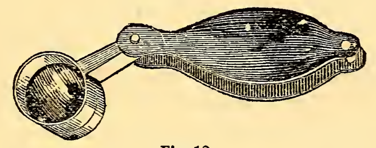


Fig. 12.

A small *magnet* should be kept on hand, for the purpose of testing reduced metals.

Nippers, for the purpose of breaking off pieces of minerals for analysis, without injuring the entire piece, are indispensable, Fig 13.

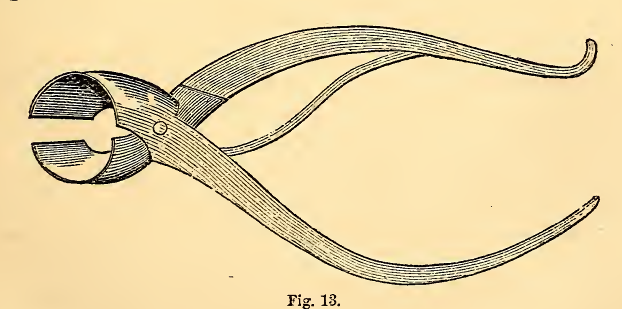


Fig. 13.

A pair of *scissors* is required to trim the wick of the lamp, and for the trimming of the edge of platinum foil.

A small *spatula* should be kept for the purpose of mixing substances with fluxes.

THE REAGENTS.

Those substances which possess the property of acting upon other substances, in such a characteristic manner that they can be recognized, either by their color, or by their effervescence, or by the peculiar precipitation produced, are termed *reagents*. The phenomena thus produced is termed *reaction*. We use those reagents, or *tests*, for the purpose of ascertaining the presence or the absence of certain substances, through the peculiar phenomena produced when brought in contact with them.

The number of reagents employed in blowpipe analysis is not great, and therefore we shall here give a brief description of their preparation and use. It is indispensably necessary that they should be chemically pure, as every admixture of a foreign substance would only produce a false result. Some of them have a strong affinity for water, or are deliquescent, and consequently absorb it greedily from the air. These must be kept in glass bottles, with glass stoppers, fitted air-tight by grinding.

A. REAGENTS OF GENERAL USE.

1. *Carbonate of Soda.*—(Na_2CO_3). Wash the bicarbonate of soda ($NaHCO_3$) upon a filter, with cold water, until the filtrate ceases to give, after neutralization with diluted nitric acid (HNO_3), a precipitate with nitrate of baryta, $Ba(NO_3)_2$, or nitrate of silver ($AgNO_3$). That left upon the filter we make red hot in a platinum, silver, or porcelain dish. One atom of carbonic acid is expelled, and the residue is carbonate of soda.

A solution of soda must not be changed by the addition of sulphide of ammonium. And when neutralized with hydrochloric acid, and evaporated to dryness, and again dissolved in water, there must be no residue left.

Carbonate of soda is an excellent agent in reduction, in consequence of its easy fusibility, whereby it causes the close contact of the oxides with the charcoal support, so that the blowpipe flame can reach every part of the substance under examination.

For the decomposition and determination of insoluble substances, particularly the silicates, carbonate of soda is indispensable. But for the latter purpose, we use with advantage a mixture of ten parts of soda and thirteen parts of dry carbonate of potash, which mixture fuses more easily than the carbonate of soda alone.

2. *Hydrate of Baryta*, $Ba(HO)_2$.—This salt is used sometimes for the detection of alkalies in silicates. Mix one part of the substance with about four parts of the hydrate of baryta, and expose it to the blowpipe flame. The hydrate of baryta combines with the silicic acid, and forms the super-basic silicate of baryta, while the oxides become free. The fused mass must be dissolved in hydrochloric acid, which converts the oxides into chlorides. Evaporate to dryness, and dissolve the residue in water. The silicic acid remains insoluble.

The hydrate of baryta is prepared by mixing six parts of finely powdered heavy-spar ($BaSO_4$) with one part of charcoal and one and a half parts of wheat flour, and exposing this mixture in a Hessian crucible with a cover to a strong and continuous red heat. The cooled chocolate-brown mass must be boiled with twenty parts of water, and, while boiling, there must be added the oxide of copper in sufficient quantity, or until the liquid will not impart a black color to a solution of acetate of lead (PbA.) The liquid must be filtered while hot, and as it cools the hydrate of baryta appears in crystals. These crystals must be washed with a little cold water, and then heated at a low temperature in a porcelain dish until the crystal water is expelled. The hydrate of baryta melts by a low red heat without losing its water of hydration.

3. *Bisulphate of Potassa* ($KHSO_4$).—At a red heat the half of the sulphuric acid of this salt becomes free, and thus

separates and expels volatile substances, by which we can recognize lithium, boracic acid, nitric acid, fluoric acid, bromine, iodine, chlorine; or it decomposes and reveals some other compounds, as, for instance, the salts of the titanic, tantalic and tungstic acids. The bisulphate of potash is also used for the purpose of converting a substance into sulphate, or to free it at once from certain constituents. These sulphates are dissolved in water, by which we are enabled to effect the separation of its various constituents.

PREPARATION.—Two parts of coarsely powdered sulphate of potash are placed in a porcelain crucible, and one part of pure sulphuric acid is poured over it. Expose this to heat over the spirit-lamp, until the whole becomes a clear liquid. The cooled mass must be of a pure white color, and may be got out of the crucible by inverting it. It must be kept in a fine powder.

4. *Oxalate of Potassa* ($K\bar{O}$).—Dissolve bioxalate of potash in water, and neutralize with carbonate of potash. Evaporate the solution at a low heat to dryness, stirring constantly towards the close of the operation. The dry residue is to be kept in the form of a powder.

The oxalate of potash, at a low red heat, eliminates a considerable quantity of carbonic oxide, which, having a strong affinity for oxygen, with which it forms carbonic acid, it is therefore a powerful agent of reduction. It is in many cases preferable to carbonate of soda.

5. *Cyanide of Potassium* (Cy, K).—In the dry method of analysis, this salt is one of the most efficient agents for the reduction of metallic oxides. It separates not only the metals from their oxygen compounds, but likewise from their sulphur compounds, while it is converted through the action of the oxygen into carbonate of potash, or, in the latter case, combines with the sulphur and forms the sulphureted cyanide of potassium. This separation is facilitated by its easy fusibility. But in many cases it melts too freely, and therefore it is better to mix it, for blowpipe analysis, with an equal quantity of soda. This mixture has great powers of reduction, and it is easily ab-

sorbed by the charcoal, while the globules of reduced metal are visible in the greatest purity.

Preparation.—Deprive the ferrocyanide of potassium (K_4FeCy_6) of its water by heating it over the spirit-lamp in a porcelain dish. Mix eight parts of this anhydrous salt with three parts of dry carbonate of potash, and fuse the mixture by a low red heat in a Hessian, or still better, in an iron crucible with a cover, until the mass flows quiet and clear, and a sample taken up with an iron spatula appears perfectly white. Pour the clear mass out into a china or porcelain dish or an iron plate, but with caution that the fine iron particles which have settled to the bottom, do not mix with it. The white fused mass must be powdered, and kept from the air. The cyanide of potassium thus prepared, contains some of the cyanate of potassa, but the admixture does not deteriorate it for blowpipe use. It must be perfectly white, free from iron, charcoal, and sulphide of potassium. The solution of it in water must give a white precipitate with a solution of lead, and when neutralized with hydrochloric acid, and evaporated to dryness, it must not give an insoluble residue by dissolving it again in water.

6. *Nitrate of Potassa, Saltpetre* (KNO_3).—Saturate boiling water with commercial saltpetre, filter while hot in a beaker glass, which is to be placed in cold water, and stir while the solution is cooling. The greater part of the saltpetre will crystallize in very fine crystals. Place these crystals upon a filter, and wash them with a little cold water, until a solution of nitrate of silver ceases to exhibit any reaction upon the filtrate. These crystals must be dried and powdered.

Saltpetre, when heated with substances easy of oxidation, yields its oxygen quite readily, and is, therefore, a powerful means of oxidation. In blowpipe analysis, we use it particularly to convert sulphides (as those of arsenic, antimony, &c.) into oxides and acids. We furthermore use saltpetre for the purpose of producing a complete oxidation of small quantities of metallic oxides, which oxidize with difficulty in the oxidation

flame, so that the color of the bead, in its highest state of oxidation, shall be visible, as for instance, manganese dissolved in the microcosmic salt.

7. *Biborate of soda, borax* — $NaH(BO_2)_2$. — Commercial borax is seldom pure enough for a reagent. A solution of borax must not give a precipitate with carbonate of potassa; or, after the addition of dilute nitric acid, it must remain clear upon the addition of nitrate of silver, or nitrate of baryta. Or a small piece of the dry salt, fused upon a platinum wire, must give a clear and uncolored glass, as well in the oxidation flame as in the reduction flame. If these tests indicate a foreign admixture, the borax must be purified by re-crystallization. These crystals are washed upon a filter, dried, and heated, to expel the crystal water, or until the mass ceases to swell up, and it is reduced to powder.

Boracic acid is incombustible, and has a strong affinity for oxides when fused with them; therefore, it not only directly combines with oxides, but it expels, by fusion, all other volatile acids from their salts. Furthermore, boracic acid promotes the oxidation of metals and sulphur, and induces haloid compounds, in the oxidation flame, to combine with the rising oxides. Borates thus made, melt generally by themselves; but admixed with borate of soda, they fuse much more readily, give a clear bead. Borax acts either as a flux, or through the formation of double salts.

In borax, we have the action of free boracic acid, as well as borate of soda, and for that reason it is an excellent reagent for blowpipe analysis.

All experiments in which borax is employed should be effected upon platinum wire. The hook of the wire should be heated red hot, and then dipped into the powdered borax. This should be exposed to the oxidation flame, when it will be fused to a bead, which adheres to the hook. This should be then dipped into the powdered substance, which will adhere to it if it is hot; but if the bead is cool, it must be previously moistened. Expose this bead to the oxidation flame until it ceases to

change, then allow it to cool, when it should be exposed to the reduction flame. Look for the following in the oxidation flame :

(1.) Whether the heated substance is fused to a clear bead or not, and whether the bead remains transparent after cooling. The beads of some substances, for instance those of the alkaline earths, are clear while hot ; but upon cooling, are milk-white and enamelled. Some substances give a clear bead when heated and when cold, but appear enamelled when heated intermittingly or with a flame which changes often from oxidation to reduction, or with an unsteady flame produced by too strong a blast. The reason is an incomplete fusion, while from the basic borate compound a part of the base is separated. As the boracic acid is capable of dissolving more in the heat, a bead will be clear while hot, enamelled when cold, as a part in the latter instance will become separated.

(2.) Whether the substance dissolves easily or not, and whether it intumesces from arising gases.

(3.) Whether the bead, when exposed to the oxidation flame, exhibits any color, and whether the color remains after the bead shall have cooled, or whether the color fades.

(4.) Whether the bead exhibits any other reaction in the reduction flame.

The bead should not be overcharged with the substance under examination, or it will become colored so deeply as not to present any transparency, or the color light enough to discern its hue.

8. *Microcosmic Salt—Phosphate of Soda and Ammonia*—($NaNH_4HPO_4$). —Dissolve six parts of phosphate of soda (Na_2HPO_4), and one part of pure chloride of Ammonium (NH^4Cl.), in two parts of boiling water, and allow it to cool. The greatest part of the formed double salt crystallizes, while the mother-liquid contains chloride of sodium, and some of the double salt. The crystals must be dissolved in as little boiling water as possible, and re-crystallized. These crystals must be dried and powdered.

When this double salt is heated, the water and the ammonia

escape, while the incombustible residue has a composition similar to borax, viz., a free acid and an easily fusible salt. The effect of it is, therefore, similar to the borax. The free phosphoric acid expels, likewise, most other acids from their combinations, and combines with metallic oxides.

For supports, the platinum wire may be used, but the hook must be smaller than when borax is used, or the bead will not adhere. As for all the other experiments with this salt, the microscosmic salt is used the same as borax.

9. *Nitrate of Cobalt.*— $Co(NO_3)_2$.— This salt can be prepared by dissolving pure oxide of cobalt in diluted nitric acid, and evaporating to dryness with a low heat. The dry residue should be dissolved in ten parts of water, and filtered. The filtrate is now ready for use, and should be kept in a bottle with a glass stopper. If the pure oxide of cobalt cannot be procured, then it may be prepared by mixing two parts of finely powdered *glance of cobalt* with four parts of saltpetre, and one part of dry carbonate of potassa with one part of water free from carbonate of soda. This mixture should be added in successive portions into a red-hot Hessian crucible, and the heat continued until the mass is fused, or at least greatly diminished in volume. The cooled mass must be triturated with hot water, and then heated with hydrochloric acid until it is dissolved and forms a dark green solution, which generally presents a gelatinous appearance, occasioned by separated silica. The solution is to be evaporated to dryness, the dry residue moistened with hydrochloric acid, boiled with water, filtered and neutralized while hot with carbonate of ammonia, until it ceases to give an acid reaction with test-paper. This must now be filtered again, and carbonate of potassa added to the filtrate as long as precipitate is produced. This precipitate is brought upon a filter and washed thoroughly, and then dissolved in diluted nitric acid. This is evaporated to dryness, and one part of it is dissolved in ten parts of water for use.

The oxide of cobalt combines, with strong heat in the oxidation flame, with various earths and infusible metallic

oxides, and thus produces peculiarly colored compounds, and is therefore used for their detection; (alumina, magnesia, oxide of zinc, oxide of tin, etc.) Some of the powdered substance is heated upon charcoal in the flame of oxidation, and moistened with a drop of the solution of the nitrate of cobalt, when the oxidation flame is thrown upon it. Alumina gives a pure blue color, the oxide of zinc a bright green, magnesia a light red, and the oxide of tin a bluish-green color; but the latter is only distinctly visible after cooling.

The dropping bottle, is the most useful apparatus for the purpose of getting small quantities of fluid. It is composed of a glass tube, drawn out to a point, with a small orifice. This tube passes through the cork of the bottle. By pressing in the cork into the neck of the bottle, the air within will be compressed, and the liquid will rise in the tube. If now we draw the cork out, with the tube filled with the fluid, and pressing the finger upon the upper orifice, the fluid can be forced out in the smallest quantity, even to a fraction of a drop.

10. *Tin.*—This metal is used in the form of foil, cut into strips about half an inch wide. Tin is very susceptible of oxidation, and therefore deprives oxidized substances of their oxygen very quickly, when heated in contact with them. It is employed in blowpipe analysis, for the purpose of producing in glass beads a lower degree of oxidation, particularly if the substance under examination contains only a small portion of such oxide. These oxides give a characteristic color to the bead, and thus are detected. The bead is heated upon charcoal in the reduction flame, with a small portion of the tin, whereby some of the tin is melted and mixes with the bead. The bead should be reduced quickly in the reduction flame, for by continuing the blast too great a while, the oxide of tin separates the other oxides in the reduced or metallic state, while we only require that they shall only be converted into a sub-oxide, in order that its peculiar color may be recognized in the bead. The addition of too much tin causes the bead

to present an unclean appearance, and prevents the required reaction.

11. *Silica* (SiO_2).—This acid does not even expel carbonic acid in the wet way, but in a glowing heat it expels the strongest volatile acids. In blowpipe analysis, we use it fused with carbonate of soda to a bead, as a test for sulphuric acid, and in some cases for phosphoric acid. Also with carbonate of soda and borax, for the purpose of separating tin from copper.

Finely powdered quartz will answer these purposes. If it cannot be procured, take well washed white sand and mix it with two parts of carbonate of soda and two parts of carbonate of potassa. Melt the materials together, pound up the cooled mass, dissolve in hot water, filter, add to the filtrate hydrochloric acid, and evaporate to dryness. Moisten the dry residue with hydrochloric acid, and boil in water. The silica remains insoluble. It should be washed well, dried, and heated, and then reduced to powder.

12. TEST-PAPERS.—(*a.*) *Blue Litmus Paper.*—Dissolve one part of litmus in six or eight parts of water, and filter. Divide the filtrate into two parts. In one of the parts neutralize the free alkali by stirring it with a glass rod dipped in diluted sulphuric acid, until the fluid appears slightly red. Then mix the two parts together, and draw slips of unsized paper, free from alkali, such as fine filtering paper. Hang these strips on a line to dry, in the shade and free from floating dust. If the litmus solution is too light, it will not give sufficient characteristic indications, and if too dark it is not sensitive enough. The blue color of the paper should be changed to red, when brought in contact with a solution containing the minutest trace of free acid; but it should be recollected that the neutral salts of the heavy metals produce the same change.

(*b.*) *Red Litmus Paper.*—The preparation of the red litmus paper is similar to the above, the acid being added until a red color is obtained. Reddened litmus paper is a very sensitive reagent for free alkalies, the carbonates of the alkalies, alkaline

earths, sulphides of the alkalies and of the alkaline earths, and alkaline salts with weak acids, such as boracic acid. These substances restore the original blue color of the litmus.

(*c.*) *Logwood Paper.*—Take bruised logwood, boil it in water, filter, and proceed as above. Logwood paper is a very delicate test for free alkalies, which impart a violet tint to it. It is sometimes used to detect hydrofluoric acid, which changes its color to yellow.

All the test-papers are to be cut into narrow strips, and preserved in closely stopped vials. The especial employment of the test-papers we shall allude to in another place.

B. ESPECIAL REAGENTS.

13. *Fused Boracic Acid* (B_2O_3).—The commercial article is sufficiently pure for blowpipe analysis. It is employed in some cases to detect phosphoric acid, and also minute traces of copper in lead compounds.

14. *Fluorspar* ($CaFl^2$).—This substance should be pounded fine and strongly heated. Fluorspar is often mixed with boracic acid, which renders it unfit for analytical purposes. Such an admixture can be detected if it be mixed with bisulphate of potassa, and exposed upon platinum wire to the interior or blue flame. It is soon fused, the boracic acid is reduced and evaporated, and by passing through the external flame it is reoxidized, and colors the flame green. We use fluorspar mixed with bisulphate of potassa as a test for lithia and boracic acid in complicated compounds.

15. *Oxalate of Nickel* ($Ni\bar{O}$).—It is prepared by dissolving the pure oxide of nickel in diluted hydrochloric acid. Evaporate to dryness, dissolve in water, and precipitate with oxalate of ammonia. The precipitate must be washed with caution upon a filter, and then dried. It is employed in blowpipe analysis to detect salts of potassa in the presence of sodium and lithium.

16. *Oxide of Copper* (CuO).—Pure metallic copper is dis-

solved in nitric acid. The solution is evaporated in a porcelain dish to dryness, and gradually heated over a spirit-lamp, until the blue color of the salt has disappeared and the mass presents a uniform black color. The oxide of copper so prepared must be powdered, and preserved in a vial. It serves to detect, in complicated compounds, minute traces of chlorine.

17. *Antimoniate of Potassa* ($K_4Sb_2O_7$).—Mix four parts of the bruised metal of antimony, with nine parts of saltpetre. Throw this mixture, in small portions, into a red-hot Hessian crucible, and keep it at a glowing heat for awhile after all the mixture is added. Boil the cooled mass with water, and dry the residue. Take two parts of this, and mix it with one part of dry carbonate of potassa, and expose this to a red heat for about half an hour. Then wash the mass in cold water, and boil the residue in water; filter, evaporate the filtrate to dryness, and then, with a strong heat, render it free of water. Powder it while it is warm, and preserve it in closed vials. It is used for the detection of small quantities of charcoal in compound substances, as it shares its oxygen with the carbonaceous matter, the antimony becomes separated, and carbonate of potassa is produced, which restores red litmus paper to blue, and effervesces with acids.

18. *Silver Foil.*—A small piece of silver foil is used for the purpose of detecting sulphur and the sulphides of the metals, which impart a dark stain to it. If no silver foil is at hand, strips of filtering paper, impregnated with acetate of lead, will answer in many cases.

19. *Nitroprusside of Sodium* ($Na_2NO, FeCy_6$).—This is a very delicate test for sulphur, and was discovered by Dr. Playfair. This test has lately been examined with considerable ability by Prof. J. W. Bailey, of West Point. If any sulphate or sulphide is heated by the blowpipe upon charcoal with the carbonate of soda, and the fused mass is placed on a watch-glass, with a little water, and a small piece of the nitroprusside of sodium is added, there will be produced a splendid purple color. This color, or reaction, will be produced from any substance contain-

ing sulphur, such as the parings of the nails, hair, albumen, etc. In regard to these latter substances, the carbonate of soda should be mixed with a little starch, which will prevent the loss of any of the sulphur by oxidation. Coil a piece of hair around a platinum wire, moisten it, and dip it into a mixture of carbonate of soda, to which a little starch has been added, and then heat it with the blowpipe, when the fused mass will give with the nitroprusside of sodium the characteristic purple reaction, indicative of the presence of sulphur. With the proper delicacy of manipulation, a piece of hair, half an inch in length, will give distinct indications of sulphur.

Preparation.—The nitroprussides of sodium and potassium (for either salt will give the above reactions), are prepared as follows: One atom (422 grains) of pulverized ferrocyanide of potassium is mixed with five atoms of commercial nitric acid, diluted with an equal quantity of water. One-fifth of this quantity (one atom) of the acid is sufficient to transfer the ferrocyanide into nitroprusside; but the use of a larger quantity is found to give the best results. The acid is poured all at once upon the ferrocyanide, the cold produced by the mixing being sufficient to moderate the action. The mixture first assumes a milky appearance, but after a little while, the salt dissolves, forming a coffee-colored solution, and gases are disengaged in abundance. When the salt is completely dissolved, the solution is found to contain ferrocyanide (red prussiate) of potassium, mixed with nitroprusside and nitrate of the same base. It is then immediately decanted into a large flask, and heated over the water-bath. It continues to evolve gas, and after awhile, no longer yields a dark blue precipitate with ferrous salts, but a dark green or slate-colored precipitate. It is then removed from the fire, and left to crystallize, whereupon it yields a large quantity of crystals of nitre, and more or less oxamide. The strongly-colored mother liquid is then neutralized with carbonate of potash or soda, according to the salt to be prepared, and the solution is boiled, whereupon it generally deposits a green or brown precipitate,

which must be separated by filtration. The liquid then contains nothing but nitroprusside and nitrate of potash or soda. The nitrates being the least soluble, are first crystallized, and the remaining liquid, on farther evaporation, yields crystals of the nitroprusside. The sodium salt crystallizes most easily.—(PLAYFAIR.)

As some substances, particularly in complicated compounds, are not detected with sufficient nicety in the dry way of analysis, it will often be necessary to resort to the wet way. It is therefore necessary to have prepared the reagents required for such testing, as every person, before he can become an expert blowpipe analyst, must be acquainted with the characteristic tests as applied in the wet way.

In the absence of nitroprusside of sodium, pulverize the assay and fuse it with soda and borax in the inner flame; place the fused mass upon a clean silver surface and wet it; a blackening of the surface of the metal indicates the presence of sulphur.

Part II.

INITIATORY ANALYSIS.

QUALITATIVE ANALYSIS refers to those examinations which relate simply to the presence or the absence of certain substances, irrespective of their quantities. But before we take cognizance of special examinations, it would facilitate the progress of the student to pass through a course of Initiatory Exercises. These at once lead into the special analysis of all those substances susceptible of examination by the blowpipe. The Initiatory Analysis is best studied by adopting the following arrangement :

1. Examinations with the glass bulb.
2. " with the open tube.
3. " upon charcoal.
4. " in the platinum forceps.
5. " in the borax bead.
6. " in microcosmic salt.
7. " in the carbonate of soda bead.
8. Confirmatory examinations.

1. EXAMINATIONS WITH THE GLASS BULB.

The glass of which the bulb is made should be entirely free from lead, otherwise fictitious results will ensue. If the bulb

be of flint glass, then by heating it, there is a slightly iridescent film caused upon the surface of the glass, which may easily be mistaken for arsenic. Besides, this kind of glass is easily fusible in the oxidating flame of the blowpipe, while, in the reducing flame, its ready decomposition would preclude its use entirely. The tube should be composed of the potash or hard Bohemian glass, should be perfectly white, and very thin, or the heat will crack it.

The tube should be perfectly clean, which can be easily attained by wrapping a clean cotton rag around a small stick, and inserting it in the tube. Before using the tube, see also that it is perfectly dry.

The quantity of the substance put into the tube for examination should be small. From one to three grains is quite sufficient, as a general rule, but circumstances vary the quantity. The sides of the tube should not catch any of the substance as it is being placed at the bottom of the tube, or into the bulb. If any of the powder, however, should adhere, it should be pushed down with a roll of clean paper, or the clean cotton rag referred to above.

In submitting the tube to the flame, it should be heated at first very gently, the heat being increased until the glass begins to soften, when the observations of what is ensuing within it may be made.

If the substance be of an organic nature, a peculiar empyreumatic odor will be given off. If the substance chars, then it may be inferred that it is of an organic nature. The matters which are given off and cause the empyreumatic odor, are a peculiar oil, ammonia, carbonic acid, acetic acid, water, cyanogen, and frequently other compounds. If a piece of paper is heated in the bulb, a dark colored oil condenses upon the sides of the tube, which has a strong empyreumatic odor. A piece of litmus paper indicates that this oil is acid, as it is quickly changed to red by contact with it. A black residue is now left in the tube, and upon examination we will find that it is charcoal. If, instead of the paper, a piece of animal substance

is placed in the bulb, the reddened litmus paper will be converted into its original blue color, while charcoal will be left at the bottom of the tube.

A changing of the substance, however, to a dark color, should not be accepted as an invariable indication of charcoal, as some inorganic bodies thus change color, but the dark substance will not be likely to be mistaken for charcoal. By igniting the suspected substance with nitrate of potassa, it can quickly be ascertained whether it is organic or not, for if the latter, the vivid deflagration will indicate it.

If the substance contains water, it will condense upon the cold portion of the tube, and may be there examined as to whether it is acid or alkaline. If the former, the matter under examination is, perhaps, vegetable ; if the latter, it is of an animal nature. The water may be that fluid absorbed, or it may form a portion of its constitution.

If the substance contain *sulphur*, the sublimate upon the cold part of the tube may be recognized by its characteristic appearance, especially if the substance should be a sulphide of tin, copper, antimony, or iron. The hyposulphites, and several other sulphides, also give off sulphur when heated. The volatile metals, mercury and arsenic, will, however, sublime without undergoing decomposition. As the sulphide of arsenic may be mistaken, from its color and appearance, for sulphur, it must be examined especially for the purpose of determining that point.

Selenium will likewise sublime by heat as does sulphur. This is the case if selenides are present. Selenium gives off the smell of decayed horse-radish.

When the persalts are heated they are reduced to protosalts, with the elimination of a part of their acid. This will be indicated by the blue litmus paper.

If some of the neutral salts containing a volatile acid be present, they will become decomposed. For instance, the red nitrous acid water of the nitrates will indicate the decomposition of the salt, especially if it be the nitrate of a metalic oxide.

If there is an odor of sulphur, then it is quite probable, if no free sulphur be present, that a hyposulphite is decomposed.

If an oxalate be present, it is decomposed with the evolution of carbonic oxide, which may be inflamed at the mouth of the tube ; but there are oxalates that give off carbonic acid gas, which, of course, will not burn. A cyanide will become decomposed and eliminate nitrogen gas, while the residue is charred. Some cyanides are, however, not thus decomposed, as the dry cyanides of the earths and alkalies.

There are several oxides of metals which will sublime, and may be thus examined in the tube. *Arsenious acid* sublimes with great ease in minute octohedral crystals. The oxides of tellurium and antimony will sublime, the latter in minute glittering needles.

There are several metals which will sublime, and may be examined in the cold portion of the tube. *Mercury* condenses upon the tube in minute globules. These often do not present the metalic appearance until they are disturbed with a glass rod, when they attract each other, and adhere as small globules. Place in the tube about a grain of red precipitate of the drug stores and apply heat, when the oxide will become decomposed, its oxygen will escape while the vaporized mercury will condense upon the cold portion of the tube, and may there be examined with a magnifying glass.

Arsenic, when vaporized, may be known by its peculiar alliaceous odor. Arsenic is vaporized from its metallic state, and likewise from its alloys. Several compounds which contain arsenic will also sublime, such as the arsenical cobalt. Place in the bulb a small piece of arsenical cobalt or "fly-stone," and apply heat. The sulphide of arsenic will first rise, but soon the arsenic will adhere to the sides of the tube.

The metals tellurium and cadmium are susceptible of solution, but the heat required is a high one. This is best done upon charcoal.

The *perchloride of mercury* sublimes undecomposed in the bulb, previously undergoing fusion.

The *protochloride of mercury* likewise sublimes, but it does not undergo fusion first, as is the case with the corrosive sublimate.

The *ammoniacal salts* all are susceptible of sublimation, which they do without leaving a residue. There are, however, several which contain fixed acids, which latter are left in the bulb. This is particularly the case with the phosphates and borates A piece of red litmus paper will readily detect the escaping ammonia, while its odor will indicate its presence with great certainty. The halogen compounds of mercury, we should have mentioned, also sublime, the red iodide giving a yellow sublimate.

The bulb is also a convenient little instrument for the purpose of heating those substances which phosphoresce, and likewise those salts that decrepitate.

Should the above reactions not be readily discerned, it should not be considered as an indication that the substances are not present, for they are frequently expelled in such combinations that the above reactions will not take place. This is often the case with sulphur, selenium, arsenic, and tellurium. It frequently happens, likewise, that these substances are in such combinations that heat alone will not sublime them ; or else two or more of them may arise together, and thus complicate the sublimate, so that the eye cannot readily detect either substance. Sometimes sulphur and arsenic will coat the tube with a metal-like appearance, which is deceptive. This coating presents a metallic lustre at its lower portion, but changing, as it progresses upward, to a dark brown, light brown, orange or yellow ; this sublimate being due to combinations of arsenic and sulphur, which compounds are volatilized at a lower temperature than metallic arsenic.

If certain reagents are mixed with many substances, changes are effected which would not ensue with heat alone. *Formiate of soda* possesses the property of readily reducing metallic oxides. When this salt is heated, it gives off a quantity of carbonic oxide gas. This gas, when in the presence of a metallic oxide, easily reduces the metal, by withdrawing its oxygen

from it, and being changed into carbonic oxide. If a little fly-stone is mixed with some formiate of soda, and heated in the bulb, the arsenic is reduced, volatilized, and condenses in the cool portion of the tube. By this method, the smallest portion of a grain of the arsenical compound may be thus examined with the greatest readiness. If the residue is now washed, by which the soda is got rid of, the metallic arsenic may be obtained in small spangles. If the compound examined be the sulphide of antimony, the one-thousandth part can be readily detected, and hence this method is admirably adapted to the examination of medicinal antimonial compounds. The arsenites of silver and copper are reduced by the formiate of soda to their metals, mixed with metallic arsenic. The mercurial salts are all reduced with the metal plainly visible as a bright silvery ring on the cool portion of the tube. The chloride and nitrate of silver are completely reduced, and may be obtained after working out the soda, as bright metallic spangles. The salts of antimony and zinc are thus reduced ; also the sulphate of cadmium. The sublimate of the latter, although in appearance not unlike that of arsenic, can easily be distingushed by its brighter color. It is, in fact, the rich yellow of this sublimate which has led artists to adopt it as one of their most valued pigments.

2. EXAMINATIONS IN THE OPEN TUBE.

The substance to be operated upon should be placed in the tube, about half an inch from the end, and the flame applied at first very cautiously, increasing gradually to the required temperature. The tube, in all these *roasting* operations, as they are termed, should be held in an inclined position. The nearer perpendicular the tube is held, the stronger is the draught of air that passes through it. If but little heat is required in the open tube operation, the spirit-lamp is the best method of applying the heat. But if a greater temperature is required, then recourse must be had to the blowpipe. Upon the angle of inclination of the tube depends the amount of air that passes

through it, and therefore, the rapidity of the draught may be easily regulated at the will of the operator. The inclination of the tube may, as a general rule, be about the angle represented in Fig. 14.

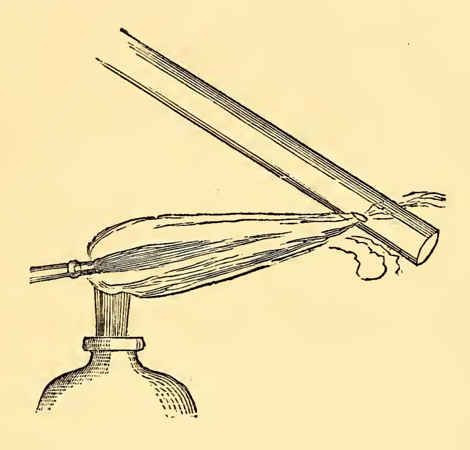


Fig. 14.

The length of the tube must be about six inches, so that the portion upon which the substance rested in a previous examination may be cut off. The portion of the tube left will answer for several similar operations.

When the substance is under examination, we should devote our attention to the nature of the sublimates, and to that of the *odors* of the gases. If sulphur be in the substance experimented upon, the characteristic odor of sulphurous acid gas will readily indicate the sulphur. If metallic sulphides, for instance, are experimented upon, the sulphurous acid gas eliminated will readily reveal their presence. As it is a property of this gas to bleach, a piece of Brazil-wood test paper should be held in the mouth of the tube, when its loss of color will indicate the presence of the sulphurous acid. It often happens, too, that a slight deposition of sulphur will be observed upon the cool por-

tion of the tube. This is particularly the case with those sulphides which yield sublimates of sulphur when heated in the bulb.

Selenium undergoes but slight oxidation, but it becomes readily volatilized, and may be observed on the cool portion of the tube. At the same time the nose, if applied close to the end of the tube, will detect the characteristic odor of rotten horse-radish. Arsenic also gives its peculiar alliaceous odor, which is so characteristic that it can be easily detected. A few of the arsenides produce this odor. The *sublimates* should be carefully observed, as they indicate often with great certainty the presence of certain substances; for instance, that of arsenic. The sublimate, in this case, presents itself as the arsenious acid, or the metallic arsenic itself. If it be the former, it may be discerned by aid of the magnifying glass as beautiful glittering octohedral crystals. If the latter, the metallic lustre will reveal it.

But it will be observed that while some of the arsenides are sublimed at a comparatively low temperature, others require a very high one.

Antimony gives a white sublimate when its salts are roasted, as the sulphide, or the antimonides themselves, or the oxide of this metal. This white sublimate is not antimonious acid, but there is mixed with it the oxide of antimony with which the acid is sublimed. As is the case with arsenious acid, the antimonious acid may, by dexterous heating, be driven from one portion of the tube to another.

Tellurium, or its acid and oxide, may be got as a sublimate in the tube. The tellurious acid, unlike the arsenious and antimonious acids, cannot be driven from one portion of the tube to another, but, on the contrary, it fuses into small clear globules, visible to the naked eye sometimes, but quite so with the aid of the magnifying glass.

Lead, or its chloride, sublimes like tellurium, and, like that substance, fuses into globules or drops.

Bismuth, or its sulphide, sublimes into an orange or brown

ish globules, when it is melted, as directed above, for tellurium. The color of the bismuth and lead oxides are somewhat similar, although that of the latter is paler.

If any mineral containing *fluorine* is fused, first with the microcosmic salt bead, then put into the tube, and the flame of the blowpipe be directed *into* the tube upon the bead, hydrofluoric acid is disengaged and attacks the inside of the tube. The fluoride of calcium, or fluorspar, may be used for this experiment.

During the roasting, a brisk current of air should be allowed to pass through the tube, whereby unoxidized matter may be prevented from volatilization, and the clogging up of the substance under examination be prevented.

3. EXAMINATIONS UPON CHARCOAL.

In making examinations upon charcoal, it is quite necessary that the student should make himself familiar with the different and characteristic appearances of the deposits upon the charcoal. In this case I have found the advice given by Dr. Sherer to be the best ; that is, to begin with the examination of the pure materials first, until the eye becomes familiarized with the appearances of their incrustations upon charcoal.

The greater part of the metals fuse when submitted to the heat of the blowpipe, and if exposed to the outer flame, they oxidize. These metals, termed the noble metals, do not oxidize, but they fuse. The metals platinum, iridium, rhodium, osmium and palladium do not fuse. The metal osmium, if exposed to the flame of oxidation, fuses and is finally dissipated as osmic acid. In the latter flame, the salts of the noble metals are reduced to the metallic state, and the charcoal is covered with the bright metal.

We shall give a brief description of the appearance of the principal elementary bodies upon being fused with charcoal. This plan is that deemed the most conducive to the progress of the student, by Berzelius, Plattner, and Sherer. Experience

has taught us that this method is the most efficient that could have been devised as an initiatory exercise for the student, ere he commences a more concise and methodical method of analysis. In these reactions upon charcoal, we shall follow nearly the language of Plattner and Sherer.

SELENIUM is not difficult of fusion, and gives off brown fumes in either the oxidation or reduction flame. The deposit upon the charcoal is of a steel-grey color, with a slightly metallic lustre. The deposit however that fuses outside of this steel-grey one is of a dull violet color, shading off to a light brown. Under the flame of oxidation this deposit is easily driven from one portion of the charcoal to another, while the application of the reducing flame volatilizes it with the evolution of a beautiful blue light. The characteristic odor of decayed horse-radish distinguishes the volatilization of this metal.

TELLURIUM.—This metal fuses with the greatest readiness, and is reduced to vapor under both flames with fumes, and coats the charcoal with a deposit of tellurous acid. This deposit is white near the centre, and is of a dark yellow near the edges. It may be driven from place to place by the flame of oxidation, while that of reduction volatilizes it with a green flame. If there be a mixture of selenium present, then the color of the flame is bluish-green.

ARSENIC.—This metal is volatilized without fusing, and covers the charcoal both in the oxidizing and reducing flames with a deposit of arsenious acid. This coating is white in the centre, and grey towards the edges, and is found some distance from the assay. By the most gentle application of the flame, it is immediately volatilized, and if touched for a moment with the reducing flame, it disappears, tinging the flame pale blue. During volatilization a strong garlic odor is distincly perceptible, very characteristic of arsenic, and by which its presence in any compound may be immediately recognized.

ANTIMONY.—This metal fuses readily, and coats the charcoal under both flames with antimonious acid. This incrustation is of a white color where thick, but of a bluish tint where it is

thin, and is found nearer to the assay than that of arsenic. When greatly heated by the flame of oxidation, it is driven from place to place without coloring the flame, but when volatilized by the flame of reduction, it tinges the flame blue. As antimonious acid is not so volatile as arsenious acid, they may thus be easily distinguished from one another.

When metallic antimony is fused upon charcoal, and the metallic bead raised to a red heat, if the blast be suspended, the fluid bead remains for some time at this temperature, giving off opaque white fumes, which are at first deposited on the surrounding charcoal, and then upon the bead itself, covering it with white, pearly crystals. The phenomenon is dependent upon the fact, that the heated button of antimony, in absorbing oxygen from the air, developes sufficient heat to maintain the metal in a fluid state, until it becomes entirely covered with crystals of antimonious acid so formed.

BISMUTH.—This metal fuses with ease, and under both flames covers the charcoal with a coating of oxide, which, while hot, is of an orange-yellow color, and after cooling, of a lemon-yellow color, passing, at the edges, into a bluish white. This white coating consists of the carbonate of bismuth. The sublimate from bismuth is formed at a less distance from the assay than is the case with antimony. It may be driven from place to place by the application of either flame; but in so doing, the oxide is first reduced by the heated charcoal, and the metallic bismuth so formed is volatilized and reoxidized. The flame is uncolored.

LEAD.—This metal readily fuses under either flame, and incrusts the charcoal with oxide at about the same distance from the assay as is the case with bismuth. The oxide is, while hot, of a dark lemon-yellow color, but upon cooling, becomes of a sulphur yellow. The carbonate which is formed upon the charcoal, beyond the oxide, is of a bluish-white color. If the yellow incrustation of the oxide be heated with the flame of oxidation, it disappears, undergoing changes similar to those of

bismuth above mentioned. Under the flame of reduction, it, however, disappears, tinging the flame blue.

Cadmium.—This metal fuses with ease, and, in the flame of oxidation, takes fire, and burns with a deep yellow color, giving off brown fumes, which coat the charcoal, to within a small distance of the assay, with oxide of cadmium. This coating exhibits its characteristic reddish-brown color most clearly when cold. Where the coating is very thin, it passes to an orange color. As oxide of cadmium is easily reduced, and the metal very volatile, the coating of oxide may be driven from place to place by the application of either flame, to neither of which does it impart any color. Around the deposit of oxide, the charcoal has occasionally a variegated tarnish.

Zinc.—This metal fuses with ease, and takes fire in the flame of oxidation, burning with a brilliant greenish-white light, and forming thick white fumes of oxide of zinc, which coat the charcoal round the assay. This coating is yellow while hot, but when perfectly cooled, becomes white. If heated with the flame of oxidation, it shines brilliantly, but is not volatilized, since the heated charcoal is, under these circumstances, insufficient to effect its reduction. Even under the reducing flame, it disappears very slowly.

Tin.—This metal fuses readily, and, in the flame of oxidation, becomes covered with oxide, which, by a strong blast, may be easily blown off. In the reducing flame, the fused metal assumes a white surface, and the charcoal becomes covered with oxide. This oxide is of a pale yellow color while hot, and is quite brilliant when the flame of oxidation is directed upon it. After cooling, it becomes white. It is found immediately around the assay, and cannot be volatilized by the application of either flame.

Molybdenum.—This metal, in powder, is infusible before the blowpipe. If heated in the outer flame, it becomes gradually oxidized, and incrusts the charcoal, at a small distance from the assay, with molybdic acid, which, near the assay, forms

transparent crystalline scales, and is elsewhere deposited as a fine powder. The incrustation, while hot, is of a yellow color, but becomes white after cooling. It may be volatilized by heating with either flame, and leaves the surface of the charcoal, when perfectly cooled, of a dark-red copper color, with a metallic lustre, due to the oxide of molybdenum, which has been formed by the reducing action of the charcoal upon the molybdic acid. In the reducing flame, metallic molybdenum remains unchanged.

SILVER.—This metal, when fused alone, and kept in this state for some time, under a strong oxidizing flame, covers the charcoal with a thin film of dark reddish-brown oxide. If the silver be alloyed with lead, a yellow incrustation of the oxide of that metal is first formed, and afterwards, as the silver becomes more pure, a dark red deposit is formed on the charcoal beyond. If the silver contains a small quantity of antimony, a white incrustation of antimonious acid is formed, which becomes red on the surface if the blast be continued. And if lead and antimony are both present in the silver, after the greater part of these metals have been volatilized, a beautiful crimson incrustation is produced upon the charcoal. This result is sometimes obtained in fusing rich silver ores on charcoal.

SULPHIDES, CHLORIDES, IODIDES, AND BROMIDES.

In blowpipe experiments, it rarely occurs that we have to deal with pure metals, which, if not absolutely non-volatile, are recognized by the incrustation they form upon charcoal. Some compound substances, when heated upon charcoal, form white incrustations, resembling that formed by antimony, and which, when heated, may, in like manner, be driven from place to place. Among these are certain sulphides, as sulphide of potassium, and sulphide of sodium, which are formed by the action of the reducing flame upon the sulphates of potassa and soda, and are, when volatilized, reconverted into those sulphates, and as such deposited on the charcoal. No incrustation is,

however, formed, until the whole of the alkaline sulphate has been absorbed into the charcoal, and has parted with its oxygen. As sulphide of potassium is more volatile than sulphide of sodium, an incrustation is formed from the former sooner than from the latter of these salts, and is considerably thicker in the former case. If the potash incrustation be touched with the reducing flame, it disappears with a violet-colored flame; and if a soda incrustation be treated in like manner, an orange-yellow flame is produced.

Sulphide of lithium, formed by heating the sulphate in the reducing flame, is volatilized in similar manner by a strong blast, although less readily than the sulphide of sodium. It affords a greyish white film, which disappears with a crimson flame when submitted to the reducing flame.

Besides the above, the sulphides of bismuth and lead give, when heated in either flame, two different incrustations, of which the more volatile is of a white color, and consists in the one case of sulphate of lead, and in the other of sulphate of bismuth. If either of these be heated under the reducing flame, it disappears in the former case with a bluish flame, in the latter unaccompanied by any visible flame. The incrustation formed nearest to the assay consists of the oxide of lead or bismuth, and is easily recognized by its color when hot and after cooling. There are many other metallic sulphides, which, when heated by the blowpipe flame, cover the charcoal with a white incrustation, as sulphide of antimony, sulphide of zinc, and sulphide of tin. In all these cases, however, the incrustation consists of the metallic oxide alone, and either volatilizes or remains unchanged, when submitted to the oxidizing flame.

Of the metallic chlorides there are many which, when heated on charcoal with the blowpipe flame, are volatilized and redeposited as a white incrustation. Among these are the chlorides of potassium, sodium, and lithium, which volatilize and cover the charcoal immediately around the assay with a thin white film, after they have been fused and absorbed into the charcoal, chloride of potassium forms the thickest deposit,

and chloride of lithium the thinnest, the latter being moreover of a greyish-white color. The chlorides of ammonium, mercury, and antimony volatilize without fusing.

The chlorides of zinc, cadmium, lead, bismuth, and tin first fuse and then cover the charcoal with two different incrustations, one of which is a white volatile chloride, and the other a less volatile oxide of the metal.

Some of the incrustations formed by metallic chlorides disappear with a colored flame when heated with the reducing flame ; thus chloride of potassium affords a violet flame, chloride of sodium an orange one, chloride of lithium a crimson flame, and chloride of lead a blue one. The other metals mentioned above volatilize without coloring the flame.

The chloride of copper fuses and colors the flame of a beautiful blue. Moreover, if a continuous blast be directed upon the salt, a part of it is driven off in the form of white fumes which smell strongly of chlorine, and the charcoal is covered with incrustations of three different colors. That which is formed nearest to the assay is of a dark grey color, the next, a dark yellow passing into brown, and the most distant of a bluish white color. If this incrustation be heated under the reducing flame, it disappears with a blue flame.

Metallic iodides and bromides behave upon charcoal in a similar manner to the chlorides. Those principally deserving of mention are the bromides and iodides of potassium and sodium. These fuse upon charcoal, are absorbed into its pores, and volatilize in the form of white fumes, which are deposited upon the charcoal at some distance from the assay. When the saline films so formed are submitted to the reducing flame, they disappear, coloring the flame in the same manner as the corresponding chlorides.

4. EXAMINATIONS IN THE PLATINUM FORCEPS.

Before the student attempts to make an examination in the platinum forceps or tongs, he should first ascertain whether

or not it will act upon the platinum. If the substance to be examined shall act chemically upon the platinum, then it should be examined on the charcoal, and the color of the flame ascertained as rigidly as possible. The following list of substances produce the color attached to them.

A. VIOLET.

Potash, and all its compounds, with the exception of the phosphate and the borate, tinge the color of the flame violet.

B. BLUE.

Chloride of copper,.................Intense blue.
Lead, ...Pale clear blue.
Bromide of copper, ...Bluish green.
Antimony, ...Bluish green.
Selenium, ...Blue.
Arsenic, ...English green.

C. GREEN.

Ammonia, ...Dark green.
Boracic acid, ...Dark green.
Copper,..........................Dark green.
Tellurium,........................Dark green.
Zinc, ...Light green.
Baryta. ....Apple green.
Phosphoric acid, ...Pale green.
Molybdic acid,.....................Apple green.
Telluric acid, ...Light green.

D. YELLOW.

Soda,............................Intense yellow.
Water, ...Feeble yellow.

E. RED.

Strontia,.........................Intense crimson.
Lithia, ...Purplish red.
Potash, ...Violet red.
Lime,..... ....Purplish red.

The student may often be deceived in regard to the colors: for instance, if a small splinter of almost any mineral be held at the point of the flame of oxidation, it will impart a very slight yellow to the flame. This is caused, doubtless, by the water contained in the mineral. If the piece of platinum wire is used, and it should be wet with the saliva, as is frequently done by the student, then the small quantity of soda existing in that fluid will color the flame of a light yellow hue.

A. THE VIOLET COLOR.

The salts of potash, with the exception of the borate and the phosphate, color the flame of a rich violet hue. This color is best discovered in the outer flame of the blowpipe, as is the case with all the other colors. The flame should be a small one, with a lamp having a small wick, while the orifice of the blowpipe must be quite small. These experiments should likewise be made in a dark room, so that the colors may be discerned with the greatest ease. In investigating with potash for the discernment of color, it should be borne in mind that the least quantity of soda will entirely destroy the violet color of the potash, by the substitution of its own strong yellow color. If there be not more than the two hundredth part of soda, the violet reaction of the potash will be destroyed. This is likewise the case with the presence of lithia, for its peculiar red color will destroy the violet of the potash. Therefore in making investigations with the silicates which contain potash, the violet color of the latter can only be discerned when they are free from soda and lithia.

B. THE BLUE COLOR.

(*a.*) *The Chloride of Copper.*—Any of the chlorides produce a blue color in the blowpipe flame, or any salt which contains chlorine will show the blue tint, as the color in this case is referable to the chlorine itself. There are, however, some

chlorides which, in consequence of the peculiar reactions of their bases, will not produce the blue color, although in these cases the blue of the chlorine will be very likely to blend itself with the color produced by the base. The chloride of copper communicates an intense blue to the flame, when fused on the platinum wire. If the heat be continued until the chlorine is driven off, then the greenish hue of the oxide of copper will be discerned.

(*b.*) *Lead.*—Metallic lead communicates to the flame a pale blue color. The oxide reacts in the same manner. The lead-salts, whose acids do not interfere with the color, impart also a fine blue to the flame, either in the platina forceps, or the crooked wire.

(*c.*) *Bromide of Copper.*—This salt colors the flame of a bluish-green color, but when the bromine is driven off, then we have the green of the oxide of copper.

(*d.*) *Antimony.*—This metal imparts a blue color to the blowpipe flame, but if the metal is in too small a quantity, then the color is a brilliant white. If antimony is fused on charcoal, the fused metal gives a blue color. The white sublimate which surrounds the fused metal, being subjected to the flame of oxidation, disappears from the charcoal with a bluish-green color.

(*e.*) *Selenium.*—If fused in the flame of oxidation, it imparts to the flame a deep blue color. The incrustation upon charcoal gives to the flame the same rich color.

(*f.*) *Arsenic.*—The arseniates and metallic arsenic itself impart to the blowpipe flame a fine blue color, provided that there is no other body present which may have a tendency to color the flame with its characteristic hue. The sublimate of arsenious acid which surrounds the assay, will give the same blue flame, when dissipated by the oxidation flame. The platinum forceps will answer for the exhibition of the color of arsenic, even though the salts be arseniates, whose bases possess the property of imparting their peculiar color to the flame, such as the arseniate of lime

C. THE GREEN COLOR.

(*a.*) *Ammonia.*—The salts of ammonia, when heated before the blowpipe, and just upon the point of disappearing, impart to the flame a feeble though dark green color. This color, however, can only be discerned in a dark room.

(*b.*) *Boracic Acid.*—If any one of the borates is mixed with two parts of a flux composed of one part of pulverized fluor-spar, and four and a half parts of bisulphate of potash, and after being melted, is put upon the coil of a platinum wire, and held at the point of the blue flame, soon after fusion takes place a dark green color is discerned, but it is not of long duration. The above process is that recommended by Dr. Turner. The green color of the borates may be readily seen by dipping them, previously moistened with sulphuric acid, into the upper part of the blue flame, when the color can be readily discerned. If soda be present, then the rich green of the boracic acid is marred by the yellow of the soda. Borax, or the biborate of soda ($NaO, 2BO_3$) may be used for this latter reaction, but if it be moistened with sulphuric acid, the green of the boracic acid can then be seen. If the borates, or minerals which contain boracic acid, are fused on charcoal with carbonate of potash, then moistened with sulphuric acid and alcohol, then the bright green of the boracic acid is produced, even if the mineral contains but a minute portion of the boracic acid.

(*c.*) *Copper.* Nearly all the ores of copper and its salts, give a bright green color to the blowpipe flame. Metallic copper likewise colors the flame green, being first oxidized. If iodine, chlorine, and bromine are present, the flame is considerably modified, but the former at least intensifies the color. Many ores containing copper also color the flame green, but the internal portion is of a bright blue color if the compound contains lead, the latter color being due to the lead. The native sulphide and carbonate of copper should be moistened

with sulphuric acid, while the former should be previously roasted. If hydrochloric acid is used for moistening the salts, then the rich green given by that moistened with the sulphuric acid is changed to a blue, being thus modified by the chlorine of the acid. Silicates containing copper, if heated in the flame in the platinum forceps, impart a rich green color to the outer flame. In fact, if any substance containing copper be submitted to the blowpipe flame, it will tinge it green, provided there be no other substance present to impart its own color to the flame, and thus modify or mar that of the copper.

(*d.*) *Tellurium.*—If the flame of reduction is directed upon the oxide of tellurium placed upon charcoal, a green color is imparted to it. If the telluric acid be placed upon platinum wire in the reduction flame, the oxidation flame is colored green. Or if the sublimate be dissipated by the flame of oxidation, it gives a green color. If selenium be present, the green color is changed to a blue.

(*e.*) *Zinc.*—The oxide of zinc, when strongly heated, gives a blue flame. This is especially the case in the reducing flame. The flame is a small one, however, and not very characteristic, as with certain preparations of zinc the blue color is changed to a bright white. The soluble salts of zinc give no blue color.

(*f.*) *Baryta.*—The soluble salts of baryta, moistened, and then submitted to the reduction flame, produce a green color. The salt should be moistened, when the color will be strongly marked in the outer flame. The insoluble salts do not produce so vivid a color as the soluble salts, and they are brighter when they have previously been moistened. The carbonate does not give a strong color, but the acetate does, so long as it is not allowed to turn to a carbonate. The chloride, when fused on the platinum wire, in the point of the reduction flame, imparts a fine green color to the oxidation flame. This tint changes finally to a faint dirty green color. The sulphate of baryta colors the flame green when heated at the point of the reduction flame. But neither the sulphate, carbonate, nor, in fact, any other salt of baryta, gives such a fine green color as the

chloride. The presence of lime does interfere with the reaction of baryta, but still does not destroy its color.

(*g.*) *Phosphoric Acid.*—The phosphates give a green color to the oxidation flame, especially when they are moistened with sulphuric acid. This is best shown with the platinum forceps. The green of phosphoric, or the phosphates, is much less intense than that of the borates or boracic acid, but yet the reaction is a certain one, and is susceptible of considerable delicacy, either with the forceps, or still better upon platinum wire. Sulphuric acid is a great aid to the development of the color, especially if other salts be present which would be liable to hide the color of the phosphoric acid. In this reaction with phosphates, the water should be expelled from them previous to melting them with sulphuric acid. They should likewise be pulverized. Should soda be present it will only exhibit its peculiar color after the phosphoric acid shall have been expelled; therefore, the green color of the phosphoric acid should be looked for immediately upon submitting the phosphate to heat.

(*h.*) *Molybdic Acid.*—If this acid or the oxide of molybdenum be exposed upon a platinum wire to the point of the reduction flame, a bright green color is communicated to the flame of oxidation. Take a small piece of the native sulphide of molybdenum, and expose it in the platinum tongs to the flame referred to above, when the green color characteristic of this metal will be exhibited.

(*i.*) *Telluric Acid.*—If the flame of reduction is directed upon a small piece of the oxide of tellurium placed upon charcoal, a bright green color is produced. Or if telluric acid be submitted to the reduction flame upon the loop of a platinum wire, it communicates to the outer flame the bright green of tellurium. If the sublimate found upon the charcoal in the first experiment be submitted to the blowpipe flame, the green color of tellurium is produced while the sublimate is volatilized. If selenium be present the green color is changed to a deep blue one

D. YELLOW.

The salts of soda all give a bright yellow color when heated in the platinum loop in the reduction flame. This color is very persistent, and will destroy the color of almost any other substance. Every mineral of which soda is a constituent, give this bright orange-yellow reaction. Even the silicate of soda itself imparts to the flame of oxidation the characteristic yellow of soda.

E. RED.

(*a.*) *Strontia.*—Moisten a small piece of the chloride of strontium, put it in the platinum forceps and submit it to the flame of reduction, when the outer flame will become colored of an intense red. If the salt of strontia should be a soluble one, the reaction is of a deeper color than if an insoluble salt is used, while the color is of a deeper crimson if the salt is moistened. If the salt be a soluble one, it should be moistened and dipped into the flame, while if it be an insoluble salt, it should be kept dry and exposed beyond the point of the flame. The carbonate of strontia should be moistened with hydrochloric acid instead of water, by which its color similates that of the chloride of strontium when moistened with water. In consequence of the decided red color which strontia communicates to flame, it is used by pyrotechnists for the purpose of making their "crimson fire."

(*b.*) *Lithia.*—The color of the flame of lithia is slightly inclined to purple. The chloride, when placed in the platinum loop, gives to the outer flame a bright red color, sometimes with a slight tinge of purple. Potash does not prevent this reaction, although it may modify it to violet; but the decided color of soda changes the red of lithia to an orange color. If much soda be present, the color of the lithia is lost entirely. The color of the chloride of lithium may be distinctly produced before the point of the blue flame, and its durability may be

the means of determining it from that of lithium, as the latter, under the same conditions, is quite evanescent. The minerals which contain lithia, frequently contain soda, and thus the latter destroys the color of the former.

(*c.*) *Potash.*—The salts of potash, if the acid does not interfere, give a purplish-red color before the blowpipe ; but as the color is more discernibly a purple, we have classed it under that color.

(*d.*) *Lime.*—The color of the flame of lime does not greatly differ from that of strontia, with the exception that it is not so decided. Arragonite and calcareous spar, moistened with hydrochloric acid, and tried as directed for strontia, produce a red light, not unlike that of strontia. The chloride of calcium gives a red tinge, but not nearly so decided as the chloride of strontium. The carbonate of lime will produce a yellowish flame for a while, until the carbonic acid is driven off, when the red color of the lime may be discerned.

If the borate or phosphate of lime be used, the green color of the acids predominates over the red of the lime. Baryta also destroys the red color of the lime, by mixing its green color with it. There is but one silicate of lime which colors the flame red, it is the variety termed tabular spar.

5. EXAMINATIONS IN THE BORAX BEAD.

In order to examine a substance in borax, the loop of the platinum wire should, after being thoroughly cleaned, and heated to redness, be quickly dipped into the powdered borax, and then quickly transferred to the flame of oxidation, and there fused. If the bead is not large enough to fill the loop of the wire, it must be subjected again to the same process. By examining the bead, both when hot and cold, by holding it up against the light, it can be soon ascertained whether it is free from dirt by the transparency, or the want of it, of the bead.

In order to make the examination of a substance, the bead

should be melted and pressed against it, when enough will adhere to answer the purpose. This powder should then be fused in the oxidation flame until it mixes with, and is thoroughly dissolved by the borax bead.

The principal objects to be determined now are : the color of the borax bead, both when heated and when cooled ; also the rapidity with which the substance dissolves in the bead, and if any gas is eliminated.

If the color of the bead is the object desired, the quantity of the substance employed must be very small, else the bead will be so deeply colored, as in some cases to appear almost opaque, as, for instance, in that of cobalt. Should this be the case, then, while the bead is still red hot, it should be pressed flat with the forceps ; or it may, while soft, be pulled out to a thin thread, whereby the color can be distinctly discovered.

Some bodies, when heated in the borax bead, present a clear bead both while hot and cold ; but if the bead be heated with the intermittent flame, or in the flame of reduction, it becomes opalescent, opaque or milk-white. The alkaline earths are instances of this kind of reaction, also glucina oxide of cerium, tantalic and titanic acids, yttria and zirconia. But if a small portion of silica should be present, then the bead becomes clear. This is likewise the case with some silicates, provided there be not too large a quantity present, that is : over the quantity necessary to saturate the borax, for, in that case, the bead will be opaque when cool.

If the bead be heated on charcoal, a small tube or cavity must be scooped out of the charcoal, the bead placed in it, and the flame of reduction played upon it. When the bead is perfectly fused, it is taken up between the platinum forceps and pressed flat, so that the color may be the more readily discerned. This quick cooling also prevents the protoxides, if there be any present, from passing into a higher degree of oxidation.

The bead should first be submitted to the oxidation flame, and any reaction carefully observed. Then the bead should be submitted to the flame of reduction. It must be observed that

the platinum forceps should not be used when there is danger of a metallic oxide being reduced, as in this case the metal would alloy with the platinum and spoil the forceps. In this case charcoal should be used for the support. If, however, there be oxides present which are not reduced by the borax, then the platinum loop may be used. Tin is frequently used for the purpose of enabling the bead to acquire a color for an oxide in the reducing flame, by its affinity for oxygen. The oxide, thus being reduced to a lower degree of oxidation, imparts its peculiar tinge to the bead as it cools.

The arsenides and sulphides, before being examined, should be roasted, and then heated with the borax bead. The arsenic of the former, it should be observed, will act on the glass tube in which the sublimation is proceeding, if the glass should contain lead.

It should be recollected that earths, metallic oxides, and metallic acids are soluble in borax, except those of the easily reducible metals, such as platinum or gold, or of mercury, which too readily vaporize. Also the metallic sulphides, after the sulphur has been driven off. Also the salts of metals, after their acids are driven off by heat. Also the nitrates and carbonates, after their acids are driven off during the fusion. Also the salts of the halogens, such as the chlorides, iodides, bromides, etc., of the metals. Also the silicates, but with great tardiness. Also the phosphates and borates that fuse in the bead without suffering decomposition. The metallic sulphides are insoluble in borax, and many of the metals in the pure state.

There are many substances which give clear beads with borax both while hot and cold, but which, upon being heated with the intermittent oxidation flame, become enamelled and opaque. The intermittent flame may be readily attained, not by varying the force of the air from the mouth, but by raising and depressing the bead before the point of the steady oxidating flame. The addition of a little nitrate of potash will often greatly facilitate the production of a color, as it

oxidizes the metal. The hot bead should be pressed upon a small crystal of the nitrate, when the bead swells, intumesces and the color is manifested in the surface of the bead.

6. EXAMINATIONS IN MICROCOSMIC SALT.

Microcosmic salt is a better flux for many metallic oxides than borax, as the colors are exhibited in it with more strength and character. Microcosmic salt is the phosphate of soda and ammonia. When it is ignited it passes into the biphosphate of soda, the ammonia being driven off. This biphosphate of soda possesses an excess of phosphoric acid, and thus has the property of dissolving a great number of substances, in fact almost any one, with the exception of silica. If the substances treated with this salt consist of sulphides or arsenides, the bead must be heated on charcoal. But if the substance experimented upon consists of earthly ingredients or metallic oxides, the platinum wire is the best. If the latter is used a few additional turns should be given to the wire in consequence of the greater fluidity of the bead over that of borax. The microcosmic salt bead possesses the advantage over that of borax, that the colors of many substances are better discerned in it, and that it separates the acids, the more volatile ones being dissipated, while the fixed ones combine with a portion of the base equally with the phosphoric acid, or else do not combine at all, but float about in the bead, as is the case particularly with silicic acid. Many of the silicates give with borax a clear bead, while they form with microcosmic salt an opalescent one.

It frequently happens, that if a metallic oxide will not give its peculiar color in one of the flames, that it will in the other, as the difference in degree with which the metal is oxidized often determines the color. If the bead is heated in the reducing flame, it is well that it should be cooled rapidly to prevent a reoxidation. Reduction is much facilitated by the employment of metallic tin, whereby the protoxide or the

reduced metal may be obtained in a comparatively brief time.

The following tables, taken from Plattner and Sherer, will present the reactions of the metallic oxides, and some of the metallic acids, in such a clear light, that the student cannot very easily be led astray, if he gives the least attention to them. It frequently happens that a tabular statement of reactions will impress facts upon the memory when long detailed descriptions will fail to do so. It is for this purpose that we subjoin the following excellent tables.

TABLE I.

A. BORAX.

1. Oxydizing flame.
2. Reducing "

B. MICROCOSMIC SALT.

1. Oxydizing flame.
2. Reducing "

A. BORAX.

1. Oxydizing flame

Color of Bead.	Substances which produce this color in the hot bead.		in the cold bead.	
	Silica		Silica	
	Alumina		Alumina	
	Oxide of Tin		Oxide of Tin	
	Telluric Acid		Telluric Acid	
	Baryta		Baryta	
	Strontia		Strontia	
	Lime		Lime	
	Magnesia		Magnesia	
	Glucina	In all proportions.	Glucina	
	Yttria		Yttria	
	Zirconia		Zirconia	
	Thoria		Thoria	With intermittent flame opaque white.
Colorless.	Oxide of Lanthanum		Oxide of Lanthanum	
			" " Silver	
	Tantalic Acid		Tantalic Acid	
	Niobic "		Niobic "	
	Pelopic "		Pelopic	
	Titanic "		Titanic	
	Tungstic "		Tungstic	
	Molybdic "	In small quantity only.	Molybdic	
	Oxide of Zinc		Oxide of Zinc	
	" " Cadmium		" " Cadmium	
	" " Lead	In large quantity yellow.	" " Lead	
	" " Bismuth		" " Bismuth	
	" " Antimony		" " Antimony	

Yellow, orange red, and reddish-brown.	Titanic Acid, yellow Tungstic " " Molybdic " dark-yellow Oxide of Zinc, pale-yellow " " Cadmium, pale-yellow " " Lead, yellow " " Bismuth, orange " " Antimony, yellow " " Cerium, red " " Iron, dark-red " " Uranium, red " " Silver Vanadic Acid, yellow Oxide of Chromium, dark-red	When in large quantity. Otherwise colorless.	Oxide of Cerium with interm. flame opaque white. Oxide of Iron, yellow Oxide of Uranium with interm. flame opaque yellow. Oxide of Silver in large proportion, with interm. flame opaline. Vanadic Acid, yellow. Oxide of Nickel, reddish-brown. " " Manganese, red to violet.
Violet or Amethyst.	Oxide of Nickel " " Manganese " " Didymium		Oxide of Didymium.
Blue.	Oxide of Cobalt		Oxide of Cobalt. " " Copper, blue to greenish-blue.
Green.	Oxide of Copper		Oxide of Chromium, with yellowish tinge.

A. BORAX.

2. Reducing flame.

Color of Bead.	Substances which produce this color in the hot bead.		Substances which produce this color in the cold bead.	
Colorless.	Silica		Silica	
	Alumina		Alumina	
	Oxide of Tin		Oxide of Tin	
	Baryta		Baryta	
	Strontia		Strontia	
	Lime		Lime	
	Magnesia		Magnesia	
	Glucina		Glucina	With an intermittent flame opaque-white.
	Yttria		Yttria	
	Zirconia		Zirconia	
	Thoria		Thoria only when saturated	
	Oxide of Lanthanum		Oxide of Lanthanum	
	" " Cerium		" " Cerium	
	Tantalic Acid		Tantalic Acid	
	Oxide of Didymium		Oxide of Didymium	
	" " Manganese		" " Manganese	
	Niobic Acid	In small proportions.	Niobic Acid	In small proportions.
	Pelopic		Pelopic	
	Oxide of Silver		Oxide of Silver	
	" " Zinc		" " Zinc	
	" " Cadmium		" " Cadmium	
	" " Lead	After long continued blowing. Otherwise grey.	" " Lead	After long continued blowing. Otherwise grey.
	" " Bismuth		" " Bismuth	
	" " Antimony		" " Antimony	
	" " Nickel		" " Nickel	
	Telluric Acid		Telluric Acid	

Yellow to brown.	Titanic Acid Tungstic " Molybdic " Vanadic "		Titanic Acid. Tungstic " Molybdic "	
Blue.	Oxide of Cobalt		Oxide of Cobalt. Titanic Acid with intermittent flame opaque-blue.	
Green.	Oxide of Iron " " Uranium " " Chromium		Oxide of Iron, bottle-green. " " Uranium, bottle-green. " " Chromium, emerald-green. Vanadic Acid, emerald-green.	
Opaque-grey. (The opacity generally becomes distinct during cooling.)	Oxide of Silver " " Zinc " " Cadmium " " Lead " " Bismuth " " Antimony " " Nickel Telluric Acid	After short blowing. Otherwise colorless.	Oxide of Silver. " " Zinc " " Cadmium " " Lead " " Bismuth " " Antimony " " Nickel Telluric Acid	After short blowing. Otherwise colorless.
	Niobic Acid Pelopic	After long continued blowing and in considerable proportion.	Niobic Acid Pelopic "	After long continued blowing and in considerable proportion.
Opaque-red and reddish-brown.	Oxide of Copper		Oxide of Copper.	

B. MICROCOSMIC SALT.

1. Oxidizing flame.

Color of Bead.	Substances which produce this color			
	in the hot bead.		in the cold bead.	
Colorless.	Silica (only slightly soluble)	In all proportions.	Silica	
	Alumina		Alumina	
	Oxide of Tin		Oxide of Tin	
	Telluric Acid		Telluric Acid	With an intermittent flame opaque white.
	Baryta		Baryta	
	Strontia		Strontia	
	Lime		Lime	
	Magnesia		Magnesia	
	Glucina		Glucina	
	Yttria		Yttria	
	Zirconia		Zirconia	
	Thoria		Thoria	
	Oxide of Lanthanum		Oxide of Lanthanum	
			" " Cerium.	
	Niobic Acid		Niobic Acid.	
	Pelopic "		Pelopic "	
	Tantalic "		Tantalic "	
	Titanic "		Titanic "	
	Tungstic "		Tungstic "	
	Oxide of Zinc	In small proportions only. In larger quantity yellow.	Oxide of Zinc.	
	" " Cadmium		" " Cadmium.	
	" " Lead		" " Lead.	
	" " Bismuth		" " Bismuth.	
	" " Antimony		" " Antimony.	

Yellow, orange, red and brown.	Tantalic Acid Titanic " Tungstic " Oxide of Zinc " " Cadmium " " Lead " " Bismuth " " Antimony " " Silver " " Cerium " " Iron " " Nickel " " Uranium Vanadic Acid Oxide of Chromium } In large quantity.	Oxide of Silver. Oxide of Iron. " " Nickel. " " Uranium, yellowish-green. Vanadic Acid.
Violet or Amethyst.	Oxide of Manganese " " Didymium	Oxide of Manganese. " " Didymium.
Blue.	Oxide of Cobalt	Oxide of Cobalt. " " Copper, to greenish-blue.
Green.	Molybdic Acid, yellowish-green Oxide of Copper	Molybdic Acid, pale yellowish-green. Oxide of Uranium, yellowish-green. " " Chromium, emerald-green.

B. MICROCOSMIC SALT.

2. Reducing flame.

Color of Bead.	Substances which produce this color in the hot bead.		Substances which produce this color in the cold bead.	
	Silica (only slightly soluble)		Silica (only slightly soluble).	
	Alumina		Alumina.	
	Oxide of Tin		Oxide of Tin.	
	Baryta		Baryta	
	Strontia		Strontia	
	Lime		Lime	
	Magnesia		Magnèsia	With an intermittent flame opaque-white.
	Glucina		Glucina	
	Yttria		Yttria	
	Zirconia		Zirconia	
	Thoria		Thoria only when saturated	
Colorless.	Oxide of Lanthanum		Oxide of Lanthanum	
	" " Cerium		" " Cerium.	
	" " Didymium		" " Didymium.	
	" " Manganese		" " Manganese.	
	Tantalic Acid		Tantalic Acid.	
	Oxide of Silver		Oxide of Silver	
	" " Zinc		" " Zinc	
	" " Cadmium	After long continued blowing. Otherwise grey.	" " Cadmium	
	" " Lead		" " Lead	After long continued blowing. Otherwise grey.
	" " Bismuth		" " Bismuth	
	" " Antimony		" " Antimony	
	" " Nickel		" " Nickel	
	Telluric Acid		Telluric Acid	

Yellow, red, and brown.	Oxide of Iron, red Titanic Acid, yellow Pelopic Acid, brown Ferruginous Titantic Acid, blood red " Niobic " " " Pelopic " " " Tungstic " " Vanadic Acid, brownish Oxide of Chromium, reddish	Oxide of Iron. Pelopic Acid. Ferruginous Titanic Acid. " Niobic " " Pelopic " " Tungstic "
Violet or Amethyst.	Niobic Acid in large proportion	Niobic Acid in large proportion. Titanic Acid.
Blue.	Oxide of Cobalt Tungstic Acid Niobic Acid in very large proportion	Oxide of Cobalt. Tungstic Acid. Niobic Acid in very large proportion.
Green.	Oxide of Uranium Molybdic Acid	Oxide of Uranium. Molybdic Acid. Vanadic " Oxide of Chromium.
Opaque-grey. (The opacity generally becomes distinct during cooling.)	Oxide of Silver " " Zinc " " Cadmium " " Lead " " Bismuth " " Antimony " " Nickel Telluric Acid	Oxide of Silver. " " Zinc. " " Cadmium. " " Lead. " " Bismuth. " " Antimony. " " Nickel. Telluric Acid.
Opaque-red and reddish-brown.	Oxide of Copper	Oxide of Copper.

TABLE II.

Metallic Oxide.	Behavior with Borax on Platinum wire		Behavior with Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
1. Oxide of Cerium, C^2O^3.	Dissolves into a red or dark yellow glass (similar to that produced by iron). During cooling, the color diminishes in intensity and becomes finally yellow. If much oxide be dissolved, an opaque bead may be obtained with an intermittent flame, and a still larger quantity renders it opaque spontaneously.	The color of the bead becomes paler, so that a bead, which is yellow in the oxidizing flame, is rendered colorless. With a large quantity of oxide the bead becomes white and crystalline on cooling.	As with borax. During the process of cooling the color entirely disappears.	Both, when hot and cold, the bead is colorless, by which character oxide of cerium may be distinguished from oxide of iron. The glass remains clear even when containing a large quantity of the oxide.
2. Oxide of Lanthanum, LaO.	Dissolves into a colorless glass, which, when sufficient oxide is present, may be rendered opaque with an intermittent flame, and becomes so spontaneously	As in the oxidizing flame.	As with borax.	No reaction.

	on cooling, when a still larger amount is dissolved.			
3. Oxide of Didymium, DO.	Dissolves to a clear dark amethystine glass.	No reaction.	As with borax.	No reaction.
4. Oxide of Manganese, Mn^2O^3.	Affords an intense amethyst color, which on cooling becomes violet. A large quantity of the oxide produces an apparently black bead, which however, if pressed flat, is seen to be transparent.	The colored bead becomes colorless. With a large amount of the oxide, this reaction is best obtained upon charcoal, and is facilitated by the addition of tin foil.	With a considerable quantity of oxide an amethyst color is obtained, but never so dark as in borax. With but little oxide a colorless bead is obtained, in which, however, the amethyst-color may be brought out by adding a little nitre. While the bead is kept fused, it froths and gives off bubbles of gas.	The colored bead immediately loses its color, either on platinum wire or on charcoal. After the reduction the fluid bead remains still.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
5. Oxide of Iron, Fe^2O^3.	With a small proportion of oxide, the glass is of a yellow color, while warm, and colorless when cold; with a larger proportion, red, while warm, and yellow, when cold; and with a still larger amount, dark-red, while warm, and dark-yellow, when cold.	Treated alone on platinum wire, the glass becomes of a bottle-green color (F^3O^4), and if touched with tin, it becomes of a pale sea-green. On charcoal with tin, it assumes at first a bottle-green color, which by continued blowing changes to a sea-green (FeO).	With a certain amount of oxide, the glass is of a yellowish-red color, which on cooling changes to yellow, then green, and finally becomes colorless. With a large addition of oxide, the color is, when warm, dark red, and passes, while cooling, into brownish-red, dark green, and finally brownish-red. During the cooling process, the colors change more rapidly than with borax.	With a small proportion of oxide there is no reaction. With a larger amount the bead is red, while warm, and becomes on cooling successively yellow, green, and russet. With the addition of tin the glass becomes, during cooling, first green and then colorless.
6. Oxide of Cobalt, CoO.	Colors the glass of an intense smalt blue both whilst hot and	As in the oxidizing flame.	As with borax, but less intensively colored. During cooling the	As in the oxidizing flames.

	when cold. When much oxide is present, the color is so deep as to appear black.		color becomes somewhat paler.	
7. Oxide of Nickel NiO.	Colors intensely. A small amount of oxide affords a glass which, while warm, is violet, and becomes of a pale reddish-brown on cooling. A larger addition produces a dark violet color in the warm and reddish-brown in the cold bead.	The oxide is reduced and the metallic particles give the bead a turbid grey appearance. If the blast be continued the metallic particles fall together without fusing, and the glass becomes colorless. This reaction is readily obtained with tin upon charcoal, and the reduced nickel fuses to a bead with the tin.	Dissolves into a reddish glass which becomes yellow on cooling. With a large addition of the oxide, the glass is brownish while hot, and orange when cold.	On platinum wire the nickeliferous bead undergoes no change. Treated with tin upon charcoal, it becomes at first opaque and grey, and after long continued blowing the reduced nickel forms a bead, and the glass remains colorless.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
8. Oxide of Zinc, ZnO.	Dissolves easily into a clear colorless glass, which, when much oxide is present, may be rendered opaque and flocculent by an intermittent flame, and becomes so spontaneously with a still larger addition. When a considerable quantity is dissolved, a glass is obtained which is pale yellow, while hot, and colorless when cold.	On platinum wire the saturated glass becomes at first opaque and grey, but by a sustained blast is again rendered clear. On charcoal the oxide is gradually reduced; the metal is volatilized and incrusts the charcoal with oxide.	As with borax.	As with borax.
	When in very large proportion, dissolves to a clear yellow glass, which becomes nearly colorless on cooling. When the oxide is	Upon charcoal ebullition takes place and the oxide is reduced. The	When in very large proportion dissolves to a clear glass, having a	On charcoal the oxide is slowly and imperfectly reduced. The reduced metal forms the characteristic incrustation on the charcoal, but the deposit

9. Oxide of Cadmium, CdO.	present in any considerable quantity, the glass can be rendered opaque with an intermittent flame, and, with a larger addition, it becomes so spontaneously on cooling.	metallic cadmium is volatilized and incrusts the charcoal with its characteristic deep yellow oxide.	yellow tinge, while hot, which disappears on cooling, and when perfectly saturated, becomes milk-white.	is thin and does not exhibit its color clearly until quite cold. The addition of tin hastens the reaction.
10. Oxide of Lead, PbO.	Dissolves readily to a clear yellow glass, which loses its color upon cooling, and when containing much oxide can be rendered dull under an intermittent flame. With a still larger addition of oxide it becomes opaline yellow on cooling.	The plumbiferous glass spreads out on charcoal, becomes turbid, bubbles up, until the whole of the oxide is reduced, when it again becomes clear. It is, however, difficult to bring the lead together into a bead.	As with borax, but a larger addition of oxide, required to produce a yellow color in the warm bead	On charcoal the plumbiferous glass becomes grey and dull. With an over dose of oxide a part is volatilized and forms an incrustation on the charcoal beyond the bead. The addition of tin does not render the glass opaque, but somewhat more dull and grey than in its absence.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
11. Oxide of Tin, SnO^2.	In small quantity dissolves slowly into a clear colorless glass, which, when cold, remains clear, and cannot be rendered opaque with an intermittent flame. If a saturated bead, which has been allowed to cool, be reheated to incipient redness, it loses its rounded form and exhibits imperfect crystallization.	A glass containing but little oxide undergoes no change. If much of the latter be present, a part may be reduced upon charcoal.	In small quantity dissolves very slowly to a colorless glass, which remains clear on cooling.	The glass undergoes no change, either on charcoal or platinum wire.
	Dissolves readily to a clear glass which with a small amount of the oxide is yellow, while warm, and becomes	A glass becomes at first grey and turbid, then begins to effervesce, which action continues during the reduction of	Dissolves in small quantity to a clear colorless glass. A larger addition affords a glass which, while warm, is yellow, and becomes colorless	On charcoal, and especially with the addition of tin, the glass remains

12. Oxide of Bismuth, BiO^3.	colorless on cooling. With a larger addition, the glass is, in the hot state, of a deep orange color, which changes to yellow and finally becomes opaline in process of cooling.	the oxide, and it finally becomes perfectly clear. If tin be added, the glass becomes at first grey from the reduced bismuth, but, when the metal is collected into a bead, the glass is again clear and colorless.	on cooling. When in sufficient proportion the glass may be rendered opaque under an intermittent flame, and a still larger addition of oxide renders the bead spontaneously opaque on cooling.	colorless and clear, while warm, but becomes on cooling of a dark grey color and opaque.
13. Oxide of Uranium, U^2O^3.	Behaves similarly to oxide of iron, with the exception that the color of the former is somewhat paler. When sufficiently saturated, the glass may be rendered of an opaque yellow by an intermittent flame.	Affords the same color as the oxide of iron. The green glass obtained in this flame, if sufficiently saturated, can be rendered black by an intermittent flame, but it has under these circumstances no enameline appearance. On charcoal, with the addition of tin, the glass takes a dark green color.	Dissolves to a clear yellow glass, which assumes a yellowish-green color on cooling.	The glass assumes a beautiful green color, which becomes more brilliant as the bead cools. The addition of tin upon charcoal produces no further change.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
14. Oxide of Copper, CuO.	Produces an intense coloration. If in small quantity, the glass is green, while warm, and becomes blue on cooling. If in large proportion, the green color is so intense as to appear black. When cool, this becomes paler, and changes to a greenish blue.	If not too saturated, the cupriferous glass soon becomes nearly colorless, but immediately on solidifying assumes a red color and becomes opaque. By long continued blowing on charcoal, the copper in the bead is reduced and separates out as a small metallic bead, leaving the glass colorless. With the addition of tin, the glass becomes of an opaque dull-red on cooling.	With an equal proportion of oxide, this salt is not so strongly colored as borax. A small amount imparts a green color in the warm and a blue in the cold. With a very large addition of oxide, the glass is opaque in the hot state, and after cooling of a greenish-blue.	A tolerably saturated glass assumes a dark green color under a good flame, and on cooling becomes of an opaque brick-red, the moment it solidifies. A glass containing but a small proportion of the oxide becomes equally red and opaque on cooling, if treated with tin upon charcoal.
15. Oxide of Mercury, HgO.	No reaction.	No reaction.	No reaction.	No reaction.

16. Oxide of Silver, AgO.	The oxide is partly dissolved and partly reduced. In small quantity, it colors the glass yellow while warm, the color disappearing on cooling. In larger quantity, the glass is yellow while warm, but during cooling becomes paler to a certain point, and then again deeper. If reheated slightly, the glass becomes opalescent.	On charcoal the argentiferous glass becomes at first grey from the reduced metal, but afterwards, when the silver is collected into a bead, it becomes clear and colorless.	Both the oxide and the metal afford a yellowish glass, which, when containing much oxide becomes opaline, exhibiting a yellow color by daylight and a red one by artificial light.	As in borax.
17. Oxide of Platinum, PtO^2. 18. Oxide of Palladium, PdO^2. 19. Oxide of Rhodium, R^2O^3. 20. Oxide of Iridium, Ir^2O^3.	Are reduced without being dissolved. The reduced metal, being infusible, cannot however be collected into a bead.	As in the oxidizing flame.	As in borax.	As in borax.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
21. Oxide of Ruthenium, Ru^2O^3. 22. Oxide of Osmium, OsO^2.				
23. Oxide of Gold, Au^2O^3.	Is reduced without being dissolved and can be collected into a bead on charcoal.	As in the oxidizing flame.	As in borax.	As in borax.
	Dissolves readily to a clear glass, which, when but little acid is present, is colorless, but when in larger proportion, yellow, and, on cooling,	In small proportion, it renders the glass yellow, in larger quantity dark-	Dissolves readily to a clear glass, which, when	The glass obtained in the oxidizing flame becomes yellow in the hot state, but on cooling assumes a beautiful violet color. If too saturated, this color is so deep as to appear opaque, but is

24. Titanic Acid, TiO^2.	colorless. When sufficiently saturated, it may be rendered opaque with an intermittent flame, and with a still larger addition of the acid becomes so spontaneously on cooling.	yellow or brown. A saturated bead assumes a blue enamel-like appearance under an intermittent flame.	sufficiently saturated, is yellow while hot, and becomes colorless on cooling.	not enameline. If the titanic acid contain iron, the glass becomes on cooling of a brownish-yellow or red color. The addition of tin neutralizes the iron, and the glass then becomes violet.
25. Tantalic Acid, TaO^3.	Dissolves readily to a clear colorless glass, which, when sufficiently saturated, may be rendered opaque with an intermittent flame, and with a larger addition of the acid becomes spontaneously enameline on cooling.	As in the oxidizing flame.	Dissolves readily to a clear glass, which, when it contains a large proportion of the acid, is yellow while warm, but becomes colorless on cooling.	The glass obtained in the oxidizing flame undergoes no change, nor does it, according to *H. Rose*, alter by the addition of sulphate of iron.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
26. Niobic Acid, Ni^2O^3.	Behaves in a similar manner to tantalic acid, but the glass requires a very large dose of the acid to render it opaque under an intermittent flame. With an increased amount of the acid, the glass is clear and yellow, while warm, but becomes on cooling turbid, and when quite cold is white.	The glass obtained in the oxidizing flame and which has become opalescent on cooling, is rendered clear in the reducing flame. With a larger addition of the acid, it becomes dull, and of a bluish-grey color on cooling, and a still larger amount renders it opaque and bluish grey.	Dissolves in large quantity to a clear colorless glass.	If the acid be not present in too large a proportion, the glass remains unchanged. An additional amount of the acid renders it violet, and a still larger quantity affords a beautiful pure blue color, similar to that produced by tungstic acid. If to such a bead some sulphate of iron be added, the glass becomes blood-red. The addition of peroxide of iron renders the glass deep yellow while warm, the color becoming paler on cooling.

27. Pelopic Acid, Pp^2O^3.	Behaves similarly to the preceding.	A bead containing sufficient of the acid to render it spontaneously opaque on cooling, has a greyish color.	Dissolves even in large quantity to a colorless glass.	With a sufficient dose of the acid, the bead becomes brown with a violet tinge. This reaction is readily obtained upon charcoal. Sulphate of iron renders the bead blood-red.
28. Oxide of Antimony, SbO^3.	Even when in large proportion, dissolves to a clear glass, which is yellow when warm, but almost entirely loses its color on cooling. On charcoal, the antimonious acid may be almost expelled, so that tin produces no further change.	A bead, that has only been treated for a short time in the oxidizing flame, when submitted to the reducing flame becomes grey and turbid from the reduced antimony. This soon volatilizes and the glass again becomes clear. The addition of tin renders the glass ash-grey or black, according to the amount of oxide it contains.	Dissolves with ebullition to a glass of a pale yellow color while warm.	On charcoal the saturated glass becomes at first dull, but as soon as the reduced antimony is volatilized, it again becomes clear. With tin, the glass is at first rendered grey by the reduced antimony, but by continued blowing is restored to clearness. Even when the glass contains but little oxide, tin produces this reaction.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
29. Tungstic Acid, WO^3.	Dissolves readily to a clear colorless glass. In large proportion it renders the borax yellow, while warm, and with a still greater addition the bead may be made opaque with an intermittent flame. If more be then added, this reaction takes place spontaneously.	When the oxide is present in small quantity, the glass undergoes no change. With a larger proportion, the glass is deep yellow while warm, and yellowish-brown when cold. This reaction takes place upon charcoal, with a small quantity of the acid. Tin produces a dark coloration, when the acid is not present in too great a quantity.	Dissolves to a clear glass, which, when saturated, is yellow in the hot state.	The glass is of a pure blue. If the tungstic acid contain iron, the glass becomes blood-red on cooling, similar to titanic acid. In this case, tin restores the blue color, or, if iron be in considerable quantity, renders it green.
	Dissolves readily and in large quantity. When but little is dissolved, the glass is yellow while hot and colorless when cold.	The glass, which has been treated in the oxidizing flame, becomes, when the acid is not present in too large a quantity, brown, and	Dissolves to a clear glass, which, when sufficient acid is present, is	The glass becomes of a bottle-green color, which on cooling, changes to a

30. Molydbic Acid, MO^3.	When in larger quantity yellow while warm and opaline when cold, and a further addition of acid renders it yellow when warm, the color, on cooling, changing first to a pale enamel blue, and then to an enamel white.	when in large quantity, perfectly opaque. In a strong flame, oxide of molybdenum is formed which is visible in the yellow glass in the form of black flakes. If the glass appear opaque, it should be flattened with the forceps.	of a yellowish-green color when warm, and becomes nearly colorless on cooling. On charcoal, the glass becomes dark, and when cool has a beautiful green color.	brilliant green, similar to that produced by oxide of chromium. The reaction on charcoal is precisely similar. Tin renders the color somewhat darker.
31. Vanadic Acid, VaO^3.	Dissolves to a clear glass, which is colorless when only a small quantity of acid is present, and yellow when containing a larger proportion.	The yellow color of the glass changes to a brown when warm and a chrome-green on cooling.	As with borax.	As with borax.

Metallic Oxides.	Behavior in Borax on Platinum wire		Behavior in Mic. Salt on Platinum wire	
	in the oxidizing flame.	in the reducing flame.	in the oxidizing flame.	in the reducing flame.
32. Oxide of Chromium, Cr^2O^3	Affords an intense color, but dissolves slowly. A small proportion colors the glass yellow when warm, and yellowish green when cold; a larger addition produces a dark red color when warm, which, on cooling, becomes yellow and finally a brilliant green with a tinge of yellow.	A small quantity of the oxide renders the glass beautifully green both when warm and when cold. A larger addition changes it to a darker emerald green. Tin produces no change in the color.	Dissolves to a clear glass which has a pink tinge while warm, but on cooling becomes dusky green, and finally brilliantly green.	As in the oxidizing flame, except that the colors are somewhat darker. Tin produces no further change.
33. Arsenious Acid, AsO^3.	No reaction.	No reaction.	No reaction.	No reaction.
34. Tellurous Acid, TeO^2.	Dissolves to a clear colorless glass which, when treated on charcoal, becomes grey and dull from particles of reduced tellurium.	As in the oxidizing flame.	As with borax.	As with borax.

7. EXAMINATIONS WITH CARBONATE OF SODA.

The carbonate of soda is pulverized and then kneaded to a paste with water; the substance to be examined, in fine powder, is also mixed with it. A small portion of this paste is placed on the charcoal, and gradually heated until the moisture is expelled, when the heat is brought to the fusion of the bead, or as high as it can be raised. Several phenomena will take place, which must be closely observed. Notice whether the substance fuses with the bead, and if so, whether there is intumescence or not. Or, whether the substance undergoes reduction; or, whether neither of these reactions takes place, and, on the contrary, the soda sinks into the charcoal, leaving the substance intact upon its surface. If intumescence takes place, the presence of either tartaric acid, molybdic acid, silicic, or tungstic acid, is indicated. The silicic acid will fuse into a bead, which becomes clear when it is cold. Titanic acid will fuse into the bead, but may be easily distinguished from the silicic acid by the bead remaining opaque when cold.

Strontia and baryta will flow into the charcoal, but lime will not. The molybdic and tungstic acids combine with the soda, forming the respective salts. These salts are absorbed by the charcoal. If too great a quantity of soda is used, the bead will be quite likely to become opaque upon cooling, while, if too small a quantity of soda is used, a portion of the substance will remain undissolved. These can be equally avoided by either the addition of soda, or the substance experimented upon, as may be required.

As silica and titanic acid are the only two substances that produce a clear bead, the student, if he gets a clear bead, may almost conclude that he is experimenting with silica, titanic acid being a rare substance. When soda is heated with silica, a slight effervescence will be the first phenomenon noticed. This is the escape of the carbonic acid of the carbonate of soda, while the silicic acid takes its place, forming a glass

with the soda. As titanic acid will not act in the same manner as silica, it can be easily distinguished by its bead not being perfectly pellucid. If the bead with which silica is fused should be tinted of a hyacinth or yellow color, this may be attributed to the presence of a small quantity of sulphur or a sulphate, and this sometimes happens from the fact of the flux containing sulphate of soda. The following metals, when exposed with carbonate of soda to the reducing flame, are wholly or partially reduced, viz. the oxides of all the noble metals, the oxides and acids of tungsten, molybdenum, arsenic, antimony, mercury, copper, tellurium, zinc, lead, bismuth, tin, cadmium, iron, nickel, and cobalt. Mercury and arsenic, as soon as they are reduced, are dissipated, while tellurium, bismuth, lead, antimony, cadmium, and zinc, are only partially volatilized, and, therefore, form sublimates on the charcoal. Those metals which are difficult of reduction should be fused with oxalate of potassa, instead of the carbonate of soda. The carbonic oxide formed from the combustion of the acid of this salt is very efficient in the reduction of these metals. Carbonate of soda is very efficient for the detection of minute quantities of manganese. The mixture of the carbonate of soda with a small addition of nitrate of potassa, and the mineral containing manganese, must be fused on platinum foil. The fused mass, when cooled, presents a fine blue color.

Part III.

THE DETERMINATION OF MINERALS BY THE AID OF THE BLOWPIPE.

TABLE OF REACTIONS.

I. The substance reduced to a powder is placed upon charcoal and heated with the blowpipe flame.

1. *It volatilizes or burns.*

2. *It yields an alliaceous odor.*
   a. Minerals having metallic lustre.
   b. Minerals without metallic lustre.

3. *It yields the odor of decayed horse-radish.*

4. *It gives off fumes of antimony.*
   a. Minerals having metallic lustre.
      α. Giving with carbonate of soda upon charcoal and in the reduction flame a bead of metallic lead.
      β. Giving with soda upon charcoal in reduction flame a bead of silver.
      γ. Giving neither silver nor lead when treated with soda upon charcoal under the reduction flame.
   b. Substances without metallic lustre.

5. *It forms upon the charcoal a whitish coating, which tinges the reduction flame green.*

(If pulverized, and heated with strong sulphuric acid, colors the flame red.)

a. Minerals of a tin-white color.

b. Minerals having lead or steel gray color.

6. *The residue has an alkaline reaction.*

a. Substances soluble in water.

α. Yielding water when heated in a glass tube.

β. Giving no water when so heated.

b. Substances insoluble or nearly so in water.

α. Effervescing when treated with hydrochloric acid.

β. Fusing with the carbonate of soda, and yielding a sulphurous mass.

γ. Giving neither of these reactions.

7. *The residue is magnetic.*

a. Minerals with metallic lustre.

b. Minerals without metallic lustre.

II. The substance mixed with the carbonate of soda is placed upon charcoal and heated in the reduction flame.

1. *The fused mass gives the sulphur reaction upon silver. There is also a metallic globule.*

a. Anhydrous substances.

b. Hydrates.

2. *The fused mass gives the sulphur reaction, but no metallic globule.*

a. Hydrates.

b. Anhydrous substances.

3. *The fused mass does not afford the sulphur reaction, but yields a metallic bead.*

a. The globule is bismuth.

b. The globule is lead.
c. The globule is silver.
d. The globule is copper.
e. The globule is some other metal.

III. The borax bead is violet in the exterior flame.

1. *Minerals with metallic lustre.*
2. *Minerals without metallic lustre.*

IV. The pulverized substance, heated with cobalt solution, exhibits a green color.

V. The substance dissolves completely in hydrochloric acid.

1. *It is fusible before the blowpipe.*

a. Yields water when treated in the glass tube.
b. Yields no water in the glass tube.

2. *It is infusible before the blowpipe.*

a. Hydrates.
b. Anhydrous substances.

VI. The substance is partially dissolved in hydrochloric acid, forming a gelatinous mass.

1. *Fusible before the blowpipe.*

a. Hydrates.
b. Anhydrous substances.

2. *Infusible before the blowpipe.*

a. Hydrates.
b. Anhydrous bodies.

VII. The substance dissolves in hydrochloric acid, leaving a residue of silica, but not in a gelatinous form.

1. *Hydrates.*
2. *Anhydrous bodies.*

VIII. The substance is insoluble in hydrochloric acid, and yields in the microcosmic salt bead a skeleton of silica.

1. *It is fusible before the blowpipe.*
2. *It is infusible.*

IX. Minerals belonging to neither of the preceding groups.

I.

THE SUBSTANCE, REDUCED TO POWDER, IS PLACED UPON CHARCOAL AND HEATED WITH THE BLOWPIPE FLAME.

1. IT VOLATILIZES OR BURNS READILY.

Sulphur — Arsenic — Selenium — Tellurium — Antimony—Selensulphur—Realgar (arsenic di-oxide)—Orpiment (arsenic tri-oxide)—Valentinite (antimonic tri-oxide) — Senarmontite (antimonic tri-oxide) — Kermes (oxide and sulphide of antimony) — Antimonocher (hydrated pentoxide of antimony)—Stiblite (antimonic oxides)—Stibine (antimonic tri-sulphide)—Salammoniac (ammonium chloride) — Muscagnite (ammonium sulphate)—Cinnabar (mercuric sulphide)—Calomel (mercurous chloride)—Sylvine (potassium chloride)—Cotunnite (lead chloride)—Tiemannite (mercuric selenide)—Graphite.

Yielding an alliaceous odor when heated on charcoal; —*Arsenic;* it volatilizes without liquefying; gives in the glass tube a dark gray metallic ring; in the platinum pincers, colors the flame pale blue; metallic lustre, tin white, dull or black. *Arsenite* sublimes without fusing in little white crystals; in the platinum pincers colors the flame blue; soluble in hot water; has a vitreous lustre.

Diffusing an odor of sulphurous acid when heated: *Sulphur,* burns with a blue flame; in the closed tube

melts and volatilizes; H (hardness*) 1.5; brittle.—*Cinnabar* volatilizes in the closed tube, yielding a black sublimate, and if previously mixed with soda or potassium cyanide, will deposit little globules of mercury; red; H 2.5.

Yielding an alliaceous and sulphurous odor when heated on charcoal: *Realgar*, melts in the closed tube, and sublimes, giving a transparent red deposit; red; becomes dark brown if treated with potash.—*Orpiment* melts and volatilizes in the closed tube, yielding a deep yellow sublimate; yellow; dissolves in potash solution.

Releasing fumes of antimony when heated on charcoal: *Native Antimony* fuses to a spherical metallic globule, but becomes coated in cooling with small crystals of antimonic oxide. The metal is bluish white, lustrous, with a specific

* The scale of hardness is as follows:

1. Talc, light green variety, easily scratched by the thumb nail.
2. Selenite (gypsum), not easily scratched by the nail; does not scratch copper.
3. Calcite, transparent. Scratches and is scratched by a copper coin.
4. Fluor spar, crystallized. Not scratched by a copper coin; does not scratch glass.
5. Apatite, transparent. Scratches glass with difficulty; easily scratched by the knife.
6. Orthoclase, white, cleavable felspar. Scratches glass easily; not easily scratched by the knife.
7. Quartz, transparent. Not scratched by the knife.
8. Topaz.
9. Sapphire.
10. Diamond.

With a knife, piece of glass, and a copper coin, the hardness is soon determined, and a clue to its name and value obtained.

In applying the test for hardness considerable care is requisite; when determining the relative hardness of two substances, each should be applied to the other. Minerals of equal hardness scratch each other.

gravity of 6.7. — *Valentinite*, transparent, pearly lustre, white, and is easily sublimed in the closed tube.—*Senarmontite* is distinguished from the preceding only by a difference in crystalline form.—*Kermes* affords a globule of antimony when heated alone upon charcoal, and releases water when heated in the closed tube; H, 1.5.—*Stiblite* yields a globule of antimony upon charcoal, but no water in the closed tube; H. = 5.5.

Yielding antimony fumes, also the odor of sulphurous acid, when heated upon charcoal; *Kermes* gives in the closed tube a sublimate, at first white, then orange; hardness 1.5, streak,* bright red. *Stibine* fuses easily in the tube, and gives, if heated strongly, a brown sublimate; metallic lustre; lead gray color. H. = 2.

Diffusing the odor of decayed horse-radish when heated on charcoal: *Selenium* — *Tiemannite*; deposits mercury on the sides of the tube if heated with carbonate of soda.

Yielding the horse-radish odor with sulphurous acid when heated on charcoal, *Selensulphur*.

Tellurium; easily fused on coal, and burns with a greenish flame; tin-white, with a metallic lustre.—*Sal-ammoniac* evaporates without fusing; is easily soluble in water; if heated with potash releases ammonia.—*Mascagnite* fuses, boils, and volatilizes, and deposits water in the closed tube; treated with soda, gives a sulphur reaction.—*Sylvine* fuses and volatilizes on the charcoal, coloring the flame a pale violet; soluble in water.—*Cotunnite* gives on the coal a greenish yellow coating; treated with soda a globule of lead is obtained; slightly soluble in water.—*Calomel* gives with carbonate of soda in the closed tube little globules of mercury; grayish white; insoluble in water.—*Graphite* fused on platinum with saltpetre yields

* The *streak* is obtained by marking with the mineral upon a white surface, preferably the surface of unglazed porcelain.

carbon dioxide, which converts the reagent into potassic carbonate ; at a high heat it burns, leaving only a slight residue.

2. YIELDING BY CALCINATION AN ALLIACEOUS ODOR.

a. Minerals with metallic lustre.

Native Arsenic—Dufrenoysite (copper and arsenic sulphides)—Arsenical Antimony—Sclervelase (lead and arsenic sulphides)—Panabase (antimony and arsenic sulphides)—Polybasite (lead, copper, antimony, and arsenic sulphides)—Smaltine (cobalt and arsenic)—Leucopyrite (iron and arsenic)—Cobaltine (cobalt, arsenic and sulphur)—Niccolite (nickel and arsenic)—Rammelsbergite (nickel, arsenic with small amount of bismuth and copper)—Disomose (nickel, arsenic, and sulphur)—Mispickel (iron, arsenic and sulphur)—Geocronite (lead, antimony and arsenic sulphides).

Arsenic and Antimony as native metals belong with this group only when the assay consists of too large fragments, or when on account of impurities in the former the volatilization is not complete.

a. Yielding hydrogen sulphide when treated with hydrochloric acid: *Dufrenoysite;* the borax bead indicates copper; fuses easily on charcoal giving arsenic and sulphurous odors, leaving finally a bead of copper.—*Panabase* yields on coal the fumes of antimony; sometimes the copper reaction is obtained in the borax bead; many specimens yield also a zinc coating on charcoal.

Borax bead blue: *Cobaltine* reduces before the blowpipe and leaves a magnetic bead.

Borax bead is of a brownish tint in the oxidation flame: *Disomose* decrepitates on charcoal.

Borax bead is green in the reduction and reddish brown in the oxidation flame: *Mispickel* reduces on charcoal and yields a magnetic globule.

With carbonate of soda yielding a bead of lead: *Scleroclase*, very brittle: H. 2.5.—*Geocronite* gives decided antimony reactions, and more feebly the copper reactions.

With carbonate of soda upon charcoal yielding a silver bead: *Polybasite* gives the antimony coating, and reduces to a dark gray grain having a metallic lustre.

β. Yielding *no* hydrogen sulphide by treatment with hydrochloric acid: *Smaltine* yields a blue borax bead, and reduces easily on the charcoal to a dark gray brittle globule, which may be taken up by the magnet.—*Leucopyrite* gives upon the charcoal a magnetic mass; gives also a dark gray streak.—*Niccolite* gives a red brown color to the borax bead in the oxidation flame; reduces on coal to a magnetic globule; has a copper-red color, a metallic lustre, and gives a dark brown streak.—*Rammelsbergite* gives reactions similar to Niccolite; reduces readily; remains incandescent some time after being removed from the flame; has a tin-white color, and gives a gray streak.

b. Minerals without metallic lustre.

Köttigite (nickel, cobalt, zinc and arsenic)—Scorodite (iron and copper, arsenates)—Symplesite (hydrated arsenate of iron)—Pitticite (iron arsenate and sulphate)—Pharmacosiderite (hydrated arsenates of iron)—Pharmacolite (copper arsenate)—Chondrarsenite (manganese, arsenate) — Erythrine (cobalt arsenate) — Nickelochre (nickel arsenate)—Pyrargyrite (silver antimony and arsenic sulphides) — Erinite (copper arsenate) — Chalkophyllite (copper arsenates)—Liroconite (copper and aluminum arsenates)—Euchroite (copper arsenates)—Olivenite (cop-

per arsenate and thosphate)—Tyrolite (copper, arsenate and calcium carbonate).

Giving in borax bead the copper reaction, and coloring the flame blue if previously wet with hydrochloric acid: — *Erinite* gives on the charcoal a copper bead; yields water in the closed tube; H.=5.5; transparent near the edges.— *Chalkophyllite* decrepitates violently and reduces to a brittle globule; emerald green color; clear green streak; H.=2. — *Tyrolite* breaks into small fragments before the blowpipe, then blackens and fuses to a steel gray bead; H.=1.5; color green, streak green and effervesces with acids.—*Euchroite* reduces before the blowpipe, first to copper arsenite, then to metallic copper; H.= 4.5; has a vitreous lustre.—*Liroconite* fuses on the charcoal and reduces to a scoriaceous mass; becomes cobalt blue when lightly heated.— *Olivenite* fuses in the platinum pincers and recrystallizes upon cooling; gives a little water in the closed tube; and reduces upon the charcoal to a brown scoria; streak varies from brown to olive green.

Köttigite gives upon the coal a coating of oxide of zinc; and affords a green color if treated with cobalt solution and heated strongly.

Erythrine gives a blue borax bead; the mineral has a pinkish tint.

Nickelochre gives a brownish bead with borax in the outer flame; color greenish yellow.

Pyrargyrite gives readily a globule of silver upon the charcoal if mixed with soda.

Chondrarsenite gives a violet color to the borax bead if brought into the outer flame.

Becoming magnetic when reduced upon charcoal: *Scorodite* reduces easily to a scoriaceous mass; H.=3.5 or 4; streak greenish white. — *Symplesite;* infusible; H.=5; streak varies from white to blue.—*Pitticite* reduced some-

what on charcoal; if plunged into water becomes transparent; H.=2.5; streak yellow.—*Pharmacosiderite* fuses on coal; in the closed tube gives off water and turns red; streak yellow.

Pharmacolite reduces on charcoal to a transparent bead; the bead sometimes tinged with blue by reason of the presence of a little cobalt; colors the flame slightly red.

3. YIELDING THE ODOR OF DECAYED HORSE-RADISH WHEN HEATED ON CHARCOAL.

Clausthalite (lead selenide) Berzellianite (copper selenide)—Tiemannite (mercury selenide)—Naumannite (silver selenide)—Zorgite (copper and lead selenide).

Clausthalite gives with soda upon charcoal a bead of lead; without soda, scales off, gives off fumes and yields a coating on the coal of red, yellow and white.—*Berzellianite* gives in the exterior flame a greenish blue borax bead; in the inner flame a reddish brown bead; upon the charcoal a malleable gray globule is obtained.—*Tiemannite* yields mercury in the closed tube, if heated with soda. H.=2.5; brittle.—*Naumannite*, with soda on charcoal gives a bead of silver; in the outer flame on charcoal it fuses quietly; in the inner flame it boils and becomes solid and incandescent.—*Zorgite* fuses very easily and reduces to a gray mass with a metallic lustre; in the borax bead exhibits the copper reaction; gives upon charcoal with soda a bead of lead.

4. WHEN HEATED UPON CHARCOAL GIVES OFF FUMES OF ANTIMONY.

a. Minerals having metallic lustre.

a. Giving a globule of lead when heated in the reduction flame upon charcoal with carbonate of soda.

Zinkenite—Jamesonite—Plagionite—Geocronite (all

lead and antimony sulphides)—Bournonite (copper, lead and antimony sulphides)—Tetrahedrite (copper, lead, silver and antimony sulphides)—Freieslebenite (silver, lead and antimony sulphides)—Kobellite (lead, iron, bismuth and antimony sulphides).

The copper reaction is obtained with:—*Bournonite:* gives in the closed tube a sublimate of sulphur; reduces easily upon the coal to scoriæ; brittle; H.=2.5; streak dark gray.—*Tetrahedrite* decrepitates before the blowpipe; fuses on charcoal and becomes gray scoriæ; H.=3—4.

Zinkenite decrepitates and reduces easily; H.=3.5.

Plagionite; brittle; H.=2.5; decrepitates before the blowpipe.

Jamesonite and *Geocronite* are easily distinguished from the above by blowpipe alone.

Kobellite colors the borax bead brown in the outer flame; gives a bead of lead which is brittle in consequence of the presence of bismuth.

Freieslebenite yields a globule of lead which contains silver.

β. Gives a globule of silver when heated in the reduction flame on charcoal with soda.

Dyscrasite (silver and antimony)—Miargyrite, Psaturose, Pyrargyrite (silver and antimony sulphides)—Polybasite (silver, copper and antimony sulphides).

Yielding sulphurous fumes when heated on charcoal: *Polybasite* borax bead indicates copper; decrepitates, and reduces readily H.=2.5; Sp. Gr. 6.5. — *Tetrahedrite*, the borax bead indicates copper; decrepitates and fuses easily; contains a little silver.—*Miargyrite;* steel gray to black in color; soft to the touch; streak red.—*Psaturose;* H.=2.5; black.

Discrasite reduces easily on charcoal, but unlike the preceding yields no sulphurous acid vapors.

γ. Giving on charcoal with soda neither lead nor silver.

Native Antimony—Ullmanite (nickel, antimony and sulphur)—Stibine (antimony sulphide)—Breithauptite (nickel and antimony)—Chalcostibite (copper and antimony sulphides).

Volatilizing completely after long heating: *Native Antimony—Stibine.*

Giving the sulphur reaction: *Ullmanite;* borax bead in the outer flame is reddish brown; H.=5; brittle streak gray. *Chalcostibite* gives the copper reaction, decrepitates before the blowpipe and reduces easily; H.=3.5; color varying from lead color to very dark gray; streak black.

Giving no sulphur reaction: *Breithauptite;* borax bead gives nickel reaction; reduces with difficulty; H.=5; streak brownish red.

b. Minerals without metallic lustre.

Stiblite (antimony oxides)—Antimony Ochre (antimonic oxide)—Jamesonite—Boulangerite (lead and antimony sulphides)—Kermes (antimony sulphide)—Pyrargyrite (silver and antimony sulphide)—Rameite (calcium and antimony oxides).

Giving the sulphur reaction: *Kermes* fuses easily and colors the flame green: H.=1.5; adamantine lustre: color varying from brownish red to cherry red; streak red or brown.—*Jamesonite* gives with soda a globule of lead; fuses easily; H.=2; gray; streak dark gray and of a metallic lustre.—*Boulangerite* yields upon charcoal with soda a globule of lead. H.=3.—*Pyrargyrite* when reduced upon

charcoal with soda a bead of silver; alone on the coal it scales off and reduces to a black globule streak red.

Stiblite yields a white coating upon the coal without reducing; reduced with soda, it yields a bead of antimony; yellow; H.=5.5.

Antimony Ochre fuses easily before the blowpipe and with considerable intumescence; gives water in the closed tube; H.=1.

Romeite alone upon the charcoal yields black scoriæ; with soda a globule of antimony is obtained; H.=6 or 7; color yellowish.

5. YIELDING ON CHARCOAL A WHITE COATING WHICH TINGES THE REDUCTION FLAME GREEN.

[The powdered substance treated with strong sulphuric acid and heated, colors the flame red.]

a. Minerals of a tin-white color.

Native Tellurium.—Argental Tellurium Altaite (lead and tellurium).

Native Tellurium volatilizes completely, giving an odor similar to selenium. H.=2.

Argental Tellurium gives if reduced with soda a silver bead; H=2.5; malleable.

Altaite yields with soda a bead of lead; alone it reduces easily upon the coal, giving a yellowish coating.

b. Minerals of a steel or lead gray color.

Tetradymite (bismuth, tellurium and sulphur)—Sylvanite (gold, silver and tellurium)—Nagyagite (lead and tellurium, and sometimes also gold and sulphur).

Giving the sulphur reaction: *Tetradymite* gives with

soda in the reduction flame a globule of bismuth; yields also an odor resembling selenium;—*Nagyagite* gives when reduced with soda a globule of lead; streak gray.

Sylvanite gives no sulphur reaction; reduces on the charcoal to a gray metallic grain; after long heating a malleable globule is obtained.

6. HAVING AN ALKALINE REACTION AFTER CALCINATION.

a. Easily soluble in water.

a. Yielding water when heated in the closed tube.

Mirabilite (sodium sulphate)—Thermonatrite—Natron—Trona (all sodium carbonates)—Epsomite (magnesium sulphate)—Kalinite (potash alum)—Mendigite (soda alum)—Tschermigite (ammonia alum)—Borax (sodium borate)—Loweite (magnesium and sodium sulphate)—Carnallite (magnesium and potassium chlorides)—Boussingaultite (ammonium, magnesium and iron sulphate)—Picromerite (magnesium and potassium sulphates).

Giving effervescence with hydrochloric acid: *Trona*, H.=2.5; fuses in the closed tube yielding much water. —*Natron* H.=1.5; fuses in the tube yielding much water; effloresces in the air. *Thermonatrite* does not fuse, and releases but little water.

Giving with soda the sulphur reaction: *Alums* giving after strong heating the blue reaction with cobalt solution. —*Potash Alum;* intumesces and tinges the flame a feeble violet.—*Soda Alum* fuses, intumesces and colors the flame yellow, especially if previously wet with hydrochloric acid. — *Ammonia Alum*, if heated with caustic potash, yields the odor of ammonia gas.—*Epsomite* gives after calcination a flesh or rather skin color with the cobalt

solution; fuses easily and with intumescence; H.=2 or 2.5.—*Mirabilite* gives no reaction with cobalt solution; fuses easily and is absorbed by the charcoal; colors the flame yellow; H.=1.5.—*Loweite* decrepitates in parting with water and then fuses quietly; H=2.5 or 3. *Boussingaultite* contains but little water; gives with potash the ammonia odor. *Picromerite* gives the flesh tint with cobalt solution; colors the flame violet, and precipitates silver nitrate by reason of containing some potassium chloride.

Borax intumesces strongly and then fuses, affording an occasional green tint to the flame. *Carnallite*, very hygrometric; colors the flame slightly violet; gives also a slight whitish coating on the charcoal; H=2 or 2.5.

β. Giving no water in the closed tube.

Nitre (potassium nitrate)—Soda Nitre—Nitrocalcite (calcium nitrate)—Arcanite (potassium sulphate)—Thesiardite (sodium sulphate)—Common Salt.

Deflagrating on charcoal: *Nitre*, coloring the flame violet: *Soda Nitre*, coloring the flame yellow: *Nitrocalcite*, coloring the flame red and deflagrating feebly.

Giving with soda the reaction of sulphur: *Arcanite* decrepitates and fuses; gives feeble potash reaction in the flame. *Thenardite* reduces only at a high temperature, coloring the flame yellow.

Common Salt yields easily to the blowpipe flame, coloring it yellow.

b. *Insoluble in water.*

α. Effervesces when treated with hydrochloric acid.

Witherite (barium carbonate) — Calcspar (calcium carbonate)—Aragonite (calcium carbonate)—Strontianite

(strontium carbonate)—Gaylussite (sodium and calcium carbonate)—Dolomite (calcium and magnesium carbonate)—Magnesite (magnesium carbonate)—Barytocalcite (barium and calcium carbonate)—Bromlite (barium and calcium carbonate)—Nemalite or Brucite (magnesium oxide hydrated) — Hydromagnesite (magnesium carbonate)—Smithsonite (zinc carbonate).

Giving water in the closed tube: *Gaylussite* colors the flame yellow; brittle; decrepitates, and fuses to an opaque globule. *Hydromagnesite* gives with cobalt nitrate the flesh tint indicative of magnesium; does not fuse nor color the flame. H=3 *Nemalite;* infusible; does not color the flame; gives the flesh tint with cobalt solution; silky lustre. H=2.

Coloring the flame green if previously wet with hydrochloric acid; *Witherite* fuses easily to a white bead having an enameled surface. *Barytocalcite* colors the flame yellowish green, and becomes opaque white with a greenish glazed covering. *Bromlite* presents the reactions of Barytocalcite; some specimens, however, afford the crimson color of strontium in the blowpipe flame.

Coloring the flame red when moistened with hydrochloric acid; *Strontianite.*

Coloring the flame orange-red when wet with hydrochloric acid; *Calcspar;* infusible, and becomes highly luminous before the blowpipe; H=3.—*Aragonite* is infusible; in the closed tube falls to powder; H=3.5 or 4.—*Dolomite* effervesces but slightly with acid; heated in a powdered state on platinum foil, the particles remain separate, whereas calcite would unite in a mass; H=3.5.—*Smithsonite* gives upon charcoal a white coating of zinc oxide.

Giving no color to the flame: *Magnesite;* infusible, but yields the flesh tint when treated with the cobalt solution.

β. Giving the sulphur reaction with the carbonate of soda.

Anhydrite (calcium sulphate)—Selenite (calcium sulphate with water)—Barytite (barium sulphate)—Celestine (strontium sulphate)—Polyhalite (potassium, calcium and magnesium sulphates) — Glauberite (calcium and sodium sulphates)—Alunite (potassium and aluminum sulphates)—Kieserite (magnesium sulphate)—Aluminite and Alunogen (aluminum sulphates).

Yielding water in the closed tube: *Selenite* becomes opaque in the flame; decrepitates, scales off and then fuses to an enameled bead; H=2; gives considerable water in the closed tube. *Polyhalite* gives but little water in the tube; fuses easily on the charcoal to a brownish bead; and dissolves in water leaving but little residue; H= 35. *Aluminite*; infusible, but reduces to a powder. *Alunogen* intumesces at first and then subsides into an infusible mass. H=2. *Kieserite* dissolves easily in water.

Calcined on charcoal and wet with hydrochloric acid gives a purple color to the flame; *Celestine* decrepitates and fuses to an enameled bead.

Calcined and wet with hydrochloric acid gives a reddish yellow color to the flame; *Karstenite* decrepitates slightly and fuses to an enameled white bead.

Calcined and wet with hydrochloric acid, colors the flame yellow; *Glauberite*, partially soluble in water; has a slightly salt taste; decrepitates before the blowpipe.

γ. Producing neither of the above reactions.

Borocalcite (calcium borate)—Pharmacolite (calcium arsenate) — Haidingerite (calcium arsenate) — Brucite (magnesium hydrate)—Boracite (magnesium borate)—Fluorspar (calcium fluoride) — Cryolite (aluminum and sodium fluorides)—Chiolite (aluminum and sodium fluo-

rides)—Natrolite (sodium hydrate and aluminum silicate) —Talc (magnesium silicate)—Spinel (magnesium and aluminum oxides).

Flame presenting the pale green of boric acid: *Borocalcite* after the volatilization of the boric acid gives the red color due to calcium; gives water in the closed tube. *Boracite* fuses with intumescence to a bead which in cooling becomes encrusted with crystals.

Giving garlic odor when heated on charcoal: *Pharmacolite* fuses to an enameled white bead. *Haidingerite* behaves much like the preceding; it contains less water and yields less under the blowpipe.

Brucite is infusible; becomes opaque white when heated; H=1.5; pearly lustre, gives a flesh-colored reaction with cobalt.—*Spinel* gives a blue reaction with cobalt solution.

When treated with sulphuric acid, yielding fluorhydric acid: *Cryolite* decrepitates, and then fuses to a transparent bead which becomes opaque upon cooling; colors the flame yellow; H=2.5. *Chiolite* presents the same reactions as cryolite; H=4. *Fluorspar* decrepitates and fuses to a transparent bead; colors the flame red. H=4.

Natrolite gives in the microcosmic salt bead a skeleton of silica; small fragments become opaque when first heated, but recover transparency at a higher temperature. H=5.5.

Talc gives a skeleton of silica in the microcosmic salt bead; and also gives the magnesia reaction with cobalt solution; scales off under the blowpipe; H=1.

7. THE RESIDUE AFTER CALCINATION IS MAGNETIC.

a. Minerals having metallic lustre.

Hematite (iron peroxide)—Magnetic Iron Ore—Craitonite (iron and titanium)—Limonite (ferric hydrate)—

Chromite (iron and chromium oxides)—Wolframite (iron, manganese and tungsten oxides)—Franklinite (iron, manganese and zinc oxides).

Limonite yields water in the closed tube; dark brown color; streak brownish yellow; H=5.5.

Hematite; infusible; H=6; yields no water; streak red.

Magnetite; anhydrous; fuses with difficulty; magnetic before calcination; streak black; H=6.

Chromite colors the borax bead green; H=6; streak brown.

Craitonite gives a violet bead with microcosmic salt in the reduction flame; streak black.

Wolframite gives a blood red bead with the microcosmic salt in reduction flame; gives a green mass if treated with sodium carbonate and nitre on platinum foil; streak, red brown to black.

Franklinite gives upon charcoal a whitish coating of zinc oxide; gives manganese reaction in the borax bead; streak, brownish red.

b. Minerals without metallic lustre.

Siderite (iron, carbonate)—Limonite—Red Hematite—Göthite (ferric hydrate)—Botryogen (ferrous and ferric sulphates)—Voltaite (iron and potassium sulphates)—Copiapite (ferric sulphate)—Chloropal (iron silicate)—Coquimbite (iron sulphate).

Giving water in the closed tube: *Limonite*; H=5.5; vitreous or adamantine lustre; streak, brownish yellow.—*Göthite* yields less water; H=4.5; brittle; thin laminæ are translucent; streak, brownish yellow.—*Botryogen* intumesces before the blowpipe; gives the sulphur reaction; vitreous lustre; streak, ochre yellow.—*Voltaite* forms

an earthy mass before the blowpipe; gives the sulphur reaction; partially soluble in water; streak, greenish gray; opaque and black.—*Coquimbite* is white, blue or green; gives the sulphur reaction; streak, white.—*Copiapite* gives sulphur reaction; transparent; yellow and with pearly lustre.—*Chloropal* gives no sulphur reaction; yields a silica skeleton in salt of phosphorus bead; color, pale dull yellow; unctuous to the touch; becomes reddish before the blowpipe.

Siderite gives no water.

II. THE SUBSTANCE MIXED WITH SODIUM CARBONATE IS PLACED UPON CHARCOAL AND HEATED IN THE REDUCTION FLAME.

1. THE FUSED MASS GIVES THE SULPHUR REACTION ON A SILVER PLATE, AND CONTAINS ALSO A METALLIC GLOBULE.

a. Anhydrous bodies.

Bismuthinite (bismuth sulphide)—Tetradymite (bismuth sulphide and bismuth tellurite)—Galena (lead sulphide)—Anglesite (lead sulphate)—Bismutite (bismuth carbonate, bismuth sulphate)—Leadhillite (lead sulphate, lead carbonate)—Lanarkite (lead, sulphate and carbonate) Aikinite (lead, bismuth and copper sulphides)—Millerite (nickel sulphide)—Linæite (cobalt sulphide)—Argyrose (silver sulphide)—Cuproplumbite (copper and lead sulphide)—Stromeyerite (copper and silver sulphide)—Stannite (iron, tin and copper sulphides)—Chalcocite (copper sulphide)—Covellite (copper sulphide)—Bornite (iron and copper sulphides)—Chalcopyrite (iron and copper sul-

phide)—Pentlandite (iron and nickel sulphides)—Costillite (copper and zinc sulphides).

The metallic globule is bismuth: *Bismutite* effervesces with hydrochloric acid; exhibits a vitreous or dull surface; color greenish or yellowish; streak, white: H=3.5. —*Tetradymite* gives the odor which distinguishes tellurium; metallic lustre; silver white color; streak, black; H=1.5. —*Bismuthinite* fuses easily and forms projections on the bead through spirting; metallic lustre; steel gray to pale yellow; streak, dull; H=2.5.—*Aikinite* gives the copper reaction; metallic lustre; steel gray color; streak, dark gray.

The metallic globule is lead: *Galena;* decrepitates in the closed tube, giving a sublimate of sulphur; metallic lustre, lead gray color; streak, dark gray; H=2.—*Anglesite* decrepitates before the blowpipe; lustre somewhat adamantine, often greasy looking; color, white, gray or brownish; streak, gray; H=3.—*Leadhillite* intumesces before the blowpipe and becomes yellow, but turns white upon cooling; yields easily a lead bead; transparent; yellowish; streak, white; H=2.5; effervesces with hydrochloric acid. —*Lanarkite* fuses to a white globule; gives readily an effervescence with hydrochloric acid; transparent; greenish white color; streak, white; H=2.—*Cuproplumbite* gives the copper reaction in the bead; the metallic globule is not as malleable as the ordinary lead globules; fuses with effervescence; color, lead gray; streak, black.

The metallic globule is nickel; *Millerite* yields a mass which may be taken up by the magnet; metallic lustre; color, yellow.—*Pentlandite* gives the iron reactions; has a metallic lustre and the color of bronze; H=4.

The metallic globule is copper: *Chalcocite* fuses upon the charcoal to a globule with numerous projections; in the reducing flame it becomes covered with an infusible

coating; metallic lustre; streak, black; H=2.5 or 3.—*Covellite* behaves like chalcocite; greasy lustre; H=1.5.—*Bornite* fuses to a magnetic steel gray globule; copper colored or iridescent; gives reactions of iron; streak, black. —*Chalcopyrite* decrepitates and then fuses to a magnetic mass; metallic lustre; yellowish white color; streak, greenish black; gives the iron reactions.—*Castillite* boils and fuses; gives upon the coal a coating of zinc oxide; color, lead gray; streak, reddish brown.—*Stromeyerite* fuses easily to a gray globule with a metallic lustre; silver may be found by the wet process; metallic lustre; lead gray color and dull streak.—*Stannite* fuses to a brittle, gray globule; gives the iron reaction; with soda upon coal, yields small beads of tin; metallic lustre; color varying from steel gray to pale yellow; streak, black.—The sulphur combinations of copper give promptly upon calcination with soda a clean bead of copper.

The metallic globule is silver: *Argentite* fuses with boiling; streak, brilliant; H=2.5.

Linnæite fuses on charcoal; colors the borax bead blue; has a tin-white color; H=5.5.

b. Minerals containing water.

Linarite (lead sulphate and copper hydrate)—Langite —Bieberite—Chalcanthite (all copper sulphates)—Brochantite (copper sulphate and copper hydrate).

Giving the copper reaction: *Linarite* gives a yellow coating upon charcoal, fusing easily; adamantine lustre; ultramarine blue color; streak, bright blue.—*Chalcanthite* whitens before the flame, intumesces, reduces and then blackens; vitreous lustre; sky blue color; streak, bluish white.—*Brochantite* fuses readily; has a vitreous lustre; transparent green color and gives a green streak.—*Langite*

differs from brochantite in its greater amount of water.—*Bieberite* colors the borax bead blue; silky or vitreous lustre; rose colored; streak, reddish white.

2. THE FUSED MASS GIVES THE SULPHUR REACTION, BUT NO METALLIC GLOBULE.

a. Minerals containing water.

Aluminite and Alunogen (both aluminum sulphates)—Johannite (uranium sulphates)—Goslarite (zinc sulphate)—Pissophanite (aluminum and iron sulphates)—Cacoxene (aluminum, iron, silica and phosphoric acid).

Becoming blue when treated with cobalt solution: *Aluminite;* infusible before the blowpipe; H=5.—*Alunogen* intumesces and subsides into an infusible mass; readily soluble in water.—*Pissophanite;* blue tint in cobalt reaction not very decisive; borax bead exhibits the iron reaction; blackens before the blowpipe.

Becoming green when treated with cobalt solution: *Goslarite* gives on charcoal a coating, yellow when hot, white when cold; intumesces on the coal and then becomes infusible and white.

Johannite before the blowpipe flame becomes a black mass and rather soft; colors the borax bead green; color, green; streak, pale green.

Cacoxene decrepitates and yields in the oxidation flame a magnetic scoriæ; the borax bead exhibits the iron reaction; yellow; streak, yellow.

b. Anhydrous Minerals.

Pyrrhotine—Pyrite—Marcasite (all iron sulphides)—Alabandite (manganese sulphide)—Hauerite (manganese sulphide—Blende (zinc sulphide)—Greenockite (cad-

mium sulphide)—Molybdenite (molybdenum sulphide)—Christophite (iron and zinc sulphides)—Bornite—Chalcopyrite (iron and copper sulphides)—Chalcocite and Covellite (both copper sulphides)—Castillite (copper and zinc sulphides)—Stannite (iron, tin and copper sulphides).

The borax bead presents the iron reaction: *Pyrite* fuses in the reduction flame to a black magnetic globule ; yellow color ; streak, gray ; H=6 to 6.5.—*Marcasite* behaves like pyrite ; yields a sulphurous odor when heated on charcoal ; greenish yellow color; streak, greenish black ; H=6 to 6.5. —*Pyrrhotite* fuses to a black magnetic mass ; is magnetic slightly before heating ; bronze color ; streak, blackish gray ; H=3.5 to 4.5.

Borax bead violet in oxidation flame: *Alabandite* fuses only on the edges ; color, brown to black ; streak, green ; H=3.5.—*Hauerite* in the closed tube gives a sulphur sublimate and a green residue ; color, brownish red ; streak, brownish red ; H=4.

Giving a coating on charcoal yellow when hot and white when cold : *Blende* decrepitates before the blowpipe but does not fuse ; streak varies from yellowish white to brown ; H=3.5.—*Christophite* gives the iron reactions ; color, velvety black ; streak, blackish brown ; H=5.

Greenockite yields only brown scoriæ ; streak varies from orange yellow to brick red.

Molybdenite ; the microcosmic salt bead is green in the reduction flame ; becomes brown when heated in the closed tube ; infusible.

Giving a globule of copper when fused with soda and borax ; also giving a brown borax bead in the reduction flame if tin-foil be added : *Chalcocite* fuses on coal to a globule which forms projections by spirting ; metallic lustre ; streak, black ; H=2.5 to 3.—*Covellite* is like the preceding, except it has a greasy lustre.—*Bornite* fuses to a

steel gray magnetic globule; copper red, or iridescent; streak, black; gives the iron reactions.—*Chalcopyrite* decrepitates and fuses to a gray magnetic mass; metallic lustre; pale yellow or iridescent; streak, greenish black; gives iron reaction.—*Castillite* fuses with bubbling; yields the zinc coating on coal; color, lead gray; streak, reddish brown.—*Stannite* fuses to a brittle globule; gives iron reactions; and with carbonate of soda on the coal yields small beads of tin; metallic lustre; H=4.5.

3. THE FUSED MASS GIVES NO SULPHUR REACTION, BUT YIELDS A METALLIC GLOBULE.

a. The globule is bismuth.

Native Bismuth—Bismite (bismuth oxide)—Bismutite (bismuth carbonate)—Eulytite (bismuth silicate).

Bismuth fuses readily, has a metallic lustre, silver white color with a slight ruddy tinge; brittle; H=2.5.—*Bismite* reduces easily to a metallic globule; easily crushed; color yellow or yellowish white; streak, yellowish white; H=1.5. —*Bismutite* reduces easily; in the closed tube it turns brown and yields water; effervesces with acids; has a vitreous lustre; color, white.—*Eulytite* fuses readily; the microcosmic salt bead presents a skeleton of silica; adamantine lustre; brown; streak, yellow to gray; H=4.5.

b. The metallic globule is lead.

Native Lead—Plattnerite (lead oxide)—Minium (lead oxide)—Matlockite (lead, oxide and chloride)—Mendipite (lead oxide and lead chloride)—Pyromorphite (lead phosphate and lead chloride)—Cerusite (lead carbonate)—Phosgenite (lead carbonate and lead chloride)—Stolzite (lead tungstate)—Wulfenite (lead molybdate)—Vanadinite

(lead chloride and lead vanadate)—Dechenite (lead vanadate—Crocoite (lead chromate)—Melanchroite (lead chromate)—Eusynchite (lead and zinc vanadates)—Vanquelinite (copper and lead chromates).

Giving the oxygen reaction: *Plattnerite;* color, iron black; streak, brown.—*Minium;* color, red; streak, orange.

Effervescing with acids: *Cerusite* decrepitates before the blowpipe; takes an orange colored coating and finally reduces to a bead of lead; H=3.—*Phosgenite* fuses easily in the exterior flame to a globule which is pale yellow upon cooling; reduces easily, yielding acid vapors.

The borax bead becomes green in the interior and yellow in the exterior flame: *Vanadinite* decrepitates strongly; fuses to a globule; emits sparks and reduces to metallic lead.—*Dechenite* fuses easily; streak, yellowish.—*Eusynchite* yields a zinc coating upon charcoal; streak, pale yellow.

The borax bead in either flame presents the green of the chromium reaction: *Crocoite* decrepitates, fuses easily and spreads over the coal; adamantine lustre; orange streak.—*Melanchroite* decrepitates slightly and reduces to a dark colored mass; streak, brick red.—*Vanquelinite* gives the copper reaction; intumesces slightly upon coal, then boils strongly and becomes a dark gray globule; streak, yellowish green.—*Pyromorphite* decrepitates in the glass tube; fuses upon charcoal in the exterior flame, to a bead which upon cooling exhibits a crystalline surface, giving at the same time a thin white coating of lead chloride; colors the flame blue; yields sometimes an odor of arsenic.

The microcosmic salt bead in the reduction flame presents the blue of tungsten: *Stolzite* fuses on charcoal to a crystalline globule with metallic lustre; streak, gray.

The microcosmic salt bead presents the green color of

molybdenum: *Wulfenite* decrepitates and then fuses; streak, white.

Mendipite upon charcoal diffuses the odor of hydrochloric acid; reduces to metallic lead.

Matlockite decrepitates and then fuses to a yellowish gray globule; the presence of chlorine in this and the preceding example is best detected by the wet process.

Native Lead, easily fusible, gives upon charcoal an abundant yellow coating; metallic lustre; streak, shining; H=1.5.

c. The metallic globule is silver.

Native Silver—Cerargyrite (silver chloride)—Bromyrite (silver bromide)—Iodyrite (silver iodide)—Amalgam (silver and mercury).

Silver fuses before the blowpipe; fibrous fracture; streak, brilliant.

Cerargyrite fuses in a candle flame; yields before the blowpipe a brownish bead; transparent; conchoidal fracture; streak, white; H=1.5.

Bromyrite; the powder is bright green but becomes rapidly gray.

Iodyrite fuses to a silver globule, coloring the flame purple; streak, brilliant; H=1.

Amalgam in the glass tube gives sublimate of mercury; on charcoal the mercury evaporates and the silver remains; H=3.

d. The globule is copper, or there is a cupreous scoria remaining.

Native Copper—Cuprite (copper sub-oxide)—Melaconite (copper oxide)—Atacamite (copper chloride and copper hydrate)—Libethenite—Thrombolite and Pseudo-

Malachite (copper phosphates and hydrates)—Malachite and Azurite (copper carbonate and hydrate)—Dioptase and Chrysocolla (copper silicate and hydrate)—Crednerite (copper and manganese oxides)—Volborthite (copper and calcium vanadate).

Are anhydrous: *Native Copper;* granular fracture; copper red color; metallic lustre; brilliant streak; H=2.5. —*Cuprite* first blackens and then reduces to a globule of copper; carmine red color; streak, brownish red; H=3.5. —*Melaconite* reduces easily to metallic copper; color, steel gray, blue or brownish black; streak, dull; H=3.—*Crednerite,* infusible and yields the manganese reaction; H=4.5.

Are hydrates:—infusible before the blowpipe: *Dioptase* assumes a blackish color in the exterior flame and red in the interior flame; streak, green; the microcosmic salt bead exhibits a skeleton of silica; H=5.—*Chrysocolla* first blackens and then turns brown before the blowpipe; streak, greenish white; shows silica in the salt of phosphorus bead; H=2.5.

Effervescing with acids: *Malachite* fuses to a globule and reduces at a high temperature; color, green; streak, green.—*Azurite* fuses and reduces before the blowpipe; color, blue; streak, blue.

Atacamite colors the flame bluish green; H=4.

Libethenite fuses on charcoal to a steel gray globule; greasy or vitreous lustre; color, green; streak, greenish yellow; H=3.5.

Pseudo-malachite fuses to a steel gray globule; vitreous lustre; green color; streak, green; H=4.5.

Thrombolite fuses to a black globule, and then reduces to copper, after long blowing; H=3, or 4.

Volborthite fuses on charcoal to a black scoria; yields water in the closed tube and turns black; color, olive green; streak, yellow; H=3.5.

e. The globule is some other metal.

Asbolite (cobalt and manganese oxides)—Zaratite (nickel carbonate)—Native Gold.

Asbolite colors the borax bead blue; gives a green mass when fused on platinum-foil with nitre and sodium carbonate.—*Zaratite* colors the borax bead in the outer flame reddish brown; effervesces with acids.—*Gold* fuses with difficulty; high specific gravity, yellow color; H=2.5.

III. THE BORAX BEAD BECOMES AMETHYST COLORED IN THE OXIDIZING FLAME.

1. MINERALS WITH METALLIC LUSTRE.

Pyrolusite—Haussmanite—Braunite—Marceline—(all manganese oxides, the latter one contains silica also) —Acerdase (manganese oxide and hydrate)—Psilomelane (manganese and barium hydrates)—Wolframite (iron and manganese tungstate).

Releasing chlorine when heated with sulphuric acid and salt: *Pyrolusite* yields much chlorine; streak, black; H=2. —*Haussmanite* gives but little chlorine; streak, brownish; H=5.5.—*Braunite* gives but little chlorine; streak, black; H=6.5.—*Marceline* resembles braunite.—*Acerdase* yields but little chlorine; gives water in the closed tube; streak, brown; H=4.—*Psilomelane* disengages but little chlorine, and yields a little water in the closed tube; lustre, not very metallic; streak, brilliant brown or black; dissolves easily in hydrochloric acid and then gives a precipitate with sulphuric acid.

Disengaging no chlorine: *Wolframite* fuses easily to a

magnetic globule covered with crystals; dissolves in hydrochloric acid, leaving a yellow residue; streak, brown or black; H=5.5.

2. MINERALS WITHOUT METALLIC LUSTRE.

Rhodchrosite (manganese carbonate)—Manganocalcite (manganese, calcium and magnesium carbonates)—Rhodonite and Tephroite (manganese silicate)—Helvite (iron, manganese and glucinum silicates with manganese sulphide)—Wad (oxides of manganese, calcium and barium) Carpholite (manganese and aluminum silicates)—Spesspartite (aluminum, manganese and calcium silicates)—Pyrochroite (manganese hydrate)—Piedmontite (aluminum and manganese silicates)—Zwieselite (manganese and iron phosphates with iron fluoride)—Childrenite (manganese, iron and aluminum phosphates)—Tantalite (iron and manganese tantalate)—Columbite (iron and manganese columbate and tantalate)—Triplite and Triphylite (iron and manganese phosphates).

Giving water in the closed tube: *Wad* disengages chlorine with sulphuric acid and salt; reduces sensibly in volume before the blowpipe; greasy lustre; brown streak; makes a mark on paper; H=1.—*Pyrochroite;* pearly lustre; white; becomes bronze colored by exposure to the air; turns first green and then brown under the action of the blowpipe; H=1 or 1.5.—*Carpholite* intumesces before the blowpipe and then fuses with difficulty to a brownish opaque enameled bead; pearly lustre; yellowish color; white streak; H=5.—*Childrenite* intumesces before the blowpipe and colors the flame bluish green; yields much water in the glass tube; has a wine yellow color; a vitreous lustre; transparent; yellowish streak; H=5.

Effervescing with hydrochloric acid: *Rhodochrosite*

decrepitates slightly before the blowpipe; streak, reddish white; H=4.—*Manganocalcite* gives a white streak; H=5; blowpipe reactions same as preceding.

Giving a skeleton of silica in the salt of phosphorus bead:

a. Soluble in hydrochloric acid: *Tephroite* fuses to a black scoria; vitreous lustre; color, gray or brown; streak, gray; H=5.5.—*Helvite* boils and fuses before the blowpipe; in the reducing flame it yields a semi-opaque bead; gives a bismuth coating on charcoal; affords also the sulphur reaction; greasy lustre; green color; gray streak; H=6.

b. Insoluble in hydrochloric acid: *Rhodonite* fuses on charcoal to a black bead; brownish red color; reddish white streak; H=5.5.—*Piedmontite* fuses easily to a black glass; reddish black color; clear gray streak; H=5 to 6.—*Spesspartite* fuses easily; brownish red color; gray streak; H=6.

Zwieselite decrepitates before the blowpipe and fuses easily; if wet with hydrochloric acid, colors the flame blue; brown color; grayish white streak; H=5.

Tantalite; infusible; gives feebly the manganese reaction; iron black color; brown streak; H=6.5.

Columbite, also infusible; gives feeble manganese reaction; blackish brown color; H=6.5.

Triplite fuses easily; boils strongly and gives a brilliant globule; streak, greenish gray to brownish yellow; H=5.5.

Triphylite fuses quietly and easily to a steel gray magnetic globule; colors the flame a pale blue-green color; sometimes reddish; gives feebly the manganese reaction; greasy lustre; greenish gray color; streak, gray.

IV. THE SUBSTANCE, PULVERIZED AND CALCINED, GIVES WHEN TREATED WITH COBALT SOLUTION UNDER THE BLOW-PIPE, A GREEN COLOR.

Zincite (zinc oxide)—Smithsonite (zinc carbonate)—Hydrozincite (hydrated zinc carbonate)—Gahnite (zinc, iron, magnesium and aluminum oxides)—Willemite (zinc silicate)—Calamine (hydrated zinc silicate).

Effervescing with hydrochloric acid: *Smithsonite*; infusible; H=5.—*Hydrozincite* yields water in the closed tube; color, white; streak, shining; H=2.5.

Giving a skeleton of silica in the microcosmic salt bead: *Calamine* decrepitates and gives off water in the closed tube; sometimes of a delicate bluish tint; streak, white; H=5.—*Willemite* yields no water; brittle and exhibits a conchoidal fracture; H=5.5.

Soluble in hydrochloric acid: *Zincite* has an adamantine lustre and yellow streak; H=4.

Insoluble in hydrochloric acid: *Gahnite* has a vitreous lustre and a white streak.

V. SOLUBLE WITHOUT RESIDUE IN HYDROCHLORIC ACID.

1. FUSIBLE BEFORE THE BLOWPIPE.

a. Yielding water in the closed tube.

Sassolite (boric acid)—Hydroboracite (calcium and magnesium borates)—Torbernite (calcium and copper

phosphates with uranium oxide)—Dufrenite and Vivianite (both iron phosphates).

Sassolite colors the flame green and gives a sublimate in the closed tube; H=1.

Hydroboracite fuses and colors the flame pale green; partially soluble in water; H=2.

Torbernite gives reaction of uranium; streak, varying from yellow to green.

Dufrenite gives the iron reaction in the borax bead; fuses on coal to an earthy globule; silky lustre; color, varying from green to brown; streak, yellowish gray; H=1.5.

Vivianite boils before the blowpipe and becomes red; lustre, vitreous; streak, bluish white; H=1.5.

b. Yielding no water in closed tube.

Wagnerite (magnesium phosphate and magnesium fluoride)—Apatite (calcium phosphate with calcium fluoride and chloride)—Amblygonite (aluminum, sodium and lithium phosphates, together with lithium and aluminum fluorides)—Chiolite and Cryolite (sodium and aluminum fluorides)—Boracite (magnesium borate with magnesium chloride)—Keilhanite (contains calcium, iron, titanium, yttrium and aluminum, mostly as silicates)—Molybdite (molybdenum oxide).

Boracite colors the flame pale green, and a very high temperature yields water; H=7.

Assuming a bluish green color when wet with sulphuric acid: *Wagnerite* boils and fuses; dissolves in dilute sulphuric acid; H=3.—*Apatite* fuses quietly; insoluble in dilute sulphuric acid; H=5. — *Amblygonite* fuses very easily; gives feebly the reaction for fluorine, also of lithium; H=2.

Cryolite fuses even in an ordinary flame to a limpid bead which becomes opaque upon cooling; in the closed tube gives the reaction for hydrofluoric acid; H=2.5.—*Chiolite*, same reactions as cryolite; H=4; both substances exhibit soda reaction in the flame.

Keilhanite; the salt of phosphorus bead contains a skeleton of silica; in the inner flame it exhibits the characteristic color of titanium compounds.

Molybdite gives molybdenum reaction; earthy appearance; yellow streak.

2. INFUSIBLE BEFORE THE BLOWPIPE.

a. Mineral hydrates.

Uraconite (uranium oxide)—Turquoise—Peganite—Fischerite (aluminum phosphates with different proportions of water)—Wavellite (aluminum phosphate and aluminum fluoride)—Lanthanite (lanthanum carbonate)—Parisite (lanthanum and cerium carbonates)—Gibbsite (aluminum hydrated oxide).

Coloring the flame green if first wet with sulphuric acid: *Turquoise* turns brown before the blowpipe; colors the flame green; greenish blue color; white streak; H=6.—*Peganite* turns pink in closed tube; otherwise like turquoise; H=3.5.—*Fischerite* turns white in tube; has a green color; H=5.—*Wavellite* in the closed tube releases hydrofluoric acid; turns white; exhibits the blue of alumina if treated with cobalt solution.

Effervescing with hydrochloric acid: *Lanthanite* browns in the closed tube; pearly or dull lustre; streak, white.—*Parisite* browns in the glass tube; vitreous lustre; streak, white.

Uraconite; the microcosmic salt bead gives the ura-

nium reaction; becomes red in the closed tube; earthy-looking; yellow; H=1.

Gibbsite whitens and exfoliates before the blowpipe; becomes luminous without fusing; becomes deep blue with cobalt solution; transparent; H=2.5.

b. Anhydrous minerals.

Uraninite (uranium oxides)—Chromic Oxide—Magnesite (magnesium carbonate)—Monazite (cerium and lanthanum phosphates)—Polycrase (titanium, iron, zirconium, yttrium and niobium oxides)—Periclasite (magnesium oxide)—Apatite (phosphate, fluoride and chloride of calcium)—Fluocerite (cerium fluoride).

Uraninite gives the reaction of uranium; greasy lustre; black streak; H=5.5.

Chromic Oxide; gives beautiful green color to the borax bead; soft and earthy.

Apatite if wet with sulphuric acid colors the flame blue-green.

Magnesite effervesces with acid and takes a flesh color when treated with cobalt solution.

Monazite if moistened with sulphuric acid, colors the flame bluish green; streak, reddish yellow.

Polycrase decrepitates before the blowpipe; heated rapidly it forms a brilliant brownish yellow mass; streak, brownish yellow.

Fluocerite yields the fluorhydric acid reaction; whitens before the blowpipe.

Periclasite becomes bright red if treated with cobalt solution; vitreous lustre; H=6.

VI. SOLUBLE IN HYDROCHLORIC ACID BUT FORMING A DEPOSIT OF GELATINOUS SILICA.

1. FUSIBLE BEFORE THE BLOWPIPE.

a. Minerals containing water.

Datholite (boro-silicate of lime)—Natrolite, Analcite and Gmelinite (sodium and aluminum silicates)—Scolecite, Laumontite, Gismondite and Thomsonite (calcium and aluminum silicates)—Philipsite (calcium, potassium and aluminum silicate)—Faujasite (calcium, sodium and aluminum silicate)—Hisingerite (ferrous and ferric silicates)—Chloropal (ferric silicate).

Communicating the yellow color of sodium to the flame: *Natrolite* becomes opaque before the blowpipe and then fuses to a transparent green; vitreous lustre; gives often an alkaline reaction when moistened; H=5.—*Analcite* fuses to a bead which is opaque but containing minute transparent bubbles or vesicles; vitreous or pearly lustre; will give the alkaline reaction; H=5.5.—*Philipsite* boils and then fuses to a transparent bead; vitreous lustre; H=4.5.—*Faujasite* gives the soda flame feebly, boils and then fuses to a white enamel; vitreous or adamantine lustre; H=7.

Gmelinite gives feebly soda reaction in the flame; fuses readily to a semi-transparent mass filled with minute bubbles; H=4.5.—*Thomsonite* gives soda flame feebly; boils and fuses to a white enamel; H=5.5.

Datholite yields a pale green in the flame, due to boric

acid; boils before the blowpipe and then fuses; greasy or vitreous lustre; brittle; H=5.5.

Scolecite intumesces before the blowpipe and some varieties curl up like a worm (hence the name); it also fuses to a white enamel, containing minute bubbles; vitreous lustre; H=5.5.

Laumontite boils and then reduces to a milk white bead; the wet powder sometimes gives an alkaline reaction; H=3.5.

Gismondite decrepitates, then becomes transparent and finally fuses to a white enamel full of air bubbles; lustre, vitreous; H=5.

Hisingerite gives iron reaction in the borax bead; fuses to a black opaque vesicular mass which is magnetic; greasy lustre; black; streak, greenish brown.

Chloropal assumes a red color before the blowpipe; is magnetic after calcination; pale yellow color; has an unctuous feel; H=2.5 to 4.5.

b. Anhydrous Minerals.

Hauynite (sodium and aluminum silicates and calcium sulphate)—Nosite (sodium and aluminum silicate with sodium sulphate)—Sodalite (sodium and aluminum silicate with sodium chloride)—Lapis Lazuli (aluminum sodium and calcium, silicates and sulphates)—Wollastonite (calcium silicate)—Eudialyte (zirconium, iron calcium and sodium silicates)—Eukolite (zirconium, calcium and sodium silicates)—Nephelite (aluminum and sodium silicate)—Wernerite (aluminum and calcium silicates)—Humboldtilite (aluminum, iron, calcium, and sodium silicates)—Tscheffkinite (titanium, cerium, iron, lanthanum and copper silicates)—Orthite (iron, calcium, aluminum and cerium silicates)—Fayalite, Lievrite (aluminum, iron and manganese silicates).

Giving sulphur reaction if treated with sodium carbonate: *Hauynite*, decrepitates and fuses to a blue green bead; lustre, vitreous; color varying from blue to white; streak bluish-white; the wet powder often giving an alkaline reaction; H=5.5.—*Lapis Lazuli* fuses with difficulty to white bead; rather vitreous lustre; bright blue color; yields hydrogen sulphide if treated with hydrochloric acid; H=5.5—*Nosite* fuses only on the edges to a glass full of bubbles; H=5.5—6.

In the borax bead saturated with copper oxide coloring the flame blue: *Sodalite* fuses to a colorless and limpid bead.—*Eudialyte* fuses to an opaque green bead.

The fused mass becoming magnetic: *Fayalite* fuses to a grayish black magnetic globule, brittle and having a magnetic lustre; the borax bead exhibits the iron reaction; the copper reaction may be obtained in the reduction flame by using tin; it is magnetic before calcination. —*Lievrite* fuses easily to a black magnetic globule; the borax bead presents the iron reaction; streak black.

Wollastonite fuses tranquilly to a transparent gloss.

Eukolite fuses very easily; after the separation of the silica the hydrochloric solution turns blue if tin foil be added; the mineral has a brownish red color.

Nephelite fuses without intumescence; greasy or vitreous lustre; wet powder, alkaline; H=5.5.

Wernerite fuses with considerable bubbling to a spongy bead; H=5 to 6.

Humboldtilite fuses to a yellowish or black bead; H=5.

Tscheffkinite boils before the blowpipe and becomes porous; throws off incandescent particles; heated more strongly it fuses to a black bead; streak, dark brown; H=5 to 5.5.

Orthite fuses with intumescence to a black gloss; yields a little water in the closed tube; color varying from brown to black; streak yellow to greenish gray; H=5.5 to 6.

2. INFUSIBLE BEFORE THE BLOWPIPE.

a. Minerals containing water.

Thorite (thorium silicate)—Cerite (cerium silicate)—Serpentine, Meerschaum, Antigorite, Monradite, Chrysotile (all magnesium silicates)—Collyrite and Allophane (aluminum silicates)—Neolite (aluminum and magnesium silicate)—Diaclasite (magnesium and iron silicates).

Becoming rose color with cobalt solution; *Serpentine* fuses upon the thin edges; blackens and yields water in the closed tube; dull or greasy lustre; H.=3.4.—*Diaclasite;* much like serpentine but exhibits a pearly lustre upon its cleavage faces, becomes brown before the blowpipe and magnetic after calcination.—*Antigorite* splits into smooth thin laminæ which may be fused under the blowpipe to a brownish yellow mass; H=2.5.—*Monradite* becomes darker colored before the blowpipe; color, yellow; lustre vitreous; H=6.—*Neolite,* greasy or silky lustre; greasy to the touch; H=1.—*Chrysotile* becomes white before the blowpipe; has a silky lustre and constitutes most of the amianthus of the serpentine rocks.—*Meerschaum* has an earthy texture; very light; it contains hygroscopic moisture which is readily given off in the closed tube; at a higher temperature yields much water; H=2.

Taking a blue color when treated with cobalt solution; *Allophane* colors the flame green; contains much water; *Collyrite* absorbs moisture; has a glimmering lustre, a greasy feel, and adheres to the tongue; H=1.5.

Thorite is orange, yellow or black, but loses its color before the blowpipe; vitreous lustre; streak, reddish gray.

Cerite, color, brown to red; streak, grayish white; H=5.5.

b. Anhydrous Minerals.

Gadolinite (magnesium, yttrium and cerium silicates)—Gehlenite (calcium and aluminum silicates)—Chrysolite and Forsterite (magnesium silicates)—Chondrodite (magnesium silicate and fluoride).

Gadolinite; the vitreous varieties become incandescent, then suddenly brilliant with intumescence; other varieties with a laminated fracture whiten, intumesce and exfoliate; black color; grayish green streak; H=6.5.

Gehlenite does not intumesce; lustre, slightly greasy; color, grayish; streak, white; H=5.5.

Chrysolite; unalterable before the blowpipe; vitreous lustre, greenish yellow color; streak, white.

Chondrodite becomes milky white before the blowpipe; heated strongly it gives feebly the reaction of fluorhydric acid; color reddish or brownish yellow; streak, white; H=6.

Forsterite behaves like chondrodite; lead gray to yellow; H=5.5.

VII. SOLUBLE IN HYDROCHLORIC ACID, LEAVING A RESIDUE OF SILICA WHICH IS NOT GELATINOUS.

1. MINERALS CONTAINING WATER.

Danburite (calcium borosilicate)—Lepidolite (lithium and aluminum silicate and lithium fluoride)—Petalite, Spodumene (lithium and aluminum silicates)—Diallage (calcium, magnesium and iron silicates)—Diopside (calcium and magnesium silicates)—Augite (calcium, magnesium,

iron and aluminum silicates)—Axinite (aluminum, calcium, iron and manganese; borates and silicates)—Tremolite (calcium and magnesium silicates)—Amphibole, Sphene (calcium titanate and silicate)—Orthoclase (potassium and aluminum silicates)—Albite (aluminum and sodium silicates)—Zoisite (calcium and aluminum silicates)—Epidote (calcium, manganese, iron and aluminum silicates)—Garnet (iron and aluminum silicates)—Idocrase (aluminum, iron, calcium and magnesium silicates)—Muscovite (potassium and aluminum silicates)—Acmite (sodium and iron silicates)—Tourmaline (aluminum, lithium and manganese, silicates and borates).

The flame presenting the coloration of lithium especially if the substance be fused with potassium bisulphate: *Lepidolite* boils, fuses easily to a bead filled with bubbles; gives reaction of fluorhydric acid; H=2.5.—*Petalite* fuses readily to a white enamel: H=6.—*Spodumene* intumesces and fuses to a translucent bead; vitreous lustre, pearly upon the cleavage faces.

The flame presents the color of boric acid: *Danburite* fuses to a bead translucent while hot, opaque when cold; color, yellow; streak, white; lustre, vitreous; H=7.—*Axinite* fuses with boiling to a deep green bead; vitreous lustre; color, brown to violet blue; H=7.—*Tourmaline*, intumesces and fuses, but with difficulty; H=7.5.

Diallage fuses before the blowpipe, has a pearly lustre on the cleavage surface; is generally bright green and opaque; H=4.

Diopside fuses to a white bead; colorless or bottle green; H=6.

Augite fuses to a black bead; color, dark green to black; the powdered mineral if wet has an alkaline reaction; H=6.

Tremolite fuses with boiling to a white bead; color, white, or greenish white.

Amphibole; same as tremolite except that it fuses to a green bead. (Note: Amphibole is the name applied to a series of minerals including tremolite: Dana calls the latter *magnesia-lime amphibole.*—Ed.)

Titanite gives titanium reaction, and fuses with some intumescence to a blackish gloss.

Orthoclase (potash feldspar) fuses quietly; color, reddish white, greyish white, sometimes green; has a distinct cleavage with a vitreous lustre frequently inclining to pearly. H=6.

Albite (soda feldspar) presents sharper angles than the preceding; fuses rather more readily, giving soda flame reaction; colors much the same as above though more frequently translucent. H=6.

Zoisite fuses with intumescence and boiling to a spongy mass of a cauliflower shape; after fusion it dissolves to a siliceous jelly in hydrochloric acid; color, gray.—*Epidote,* same as preceding; color of the fused mass is brown or black; color of the mineral is a lively green.

Garnet fuses quietly; concentrated acids attack it slightly; H=7.—*Vesuvianite*, or *Idocrase*, much the same as preceding; fuses to a greenish or brownish gloss; H=6.5. *Muscovite* (potash mica) loses its transparency before the blowpipe, becomes white and brittle and finally fuses to an enamel; in a closed tube yields water which shows a fluorine reaction. H=2 to 2.5.

Acmite fuses easily to a black bead; exhibits iron reaction in the borax bead; is strongly attacked by acids; streak, grayish yellow.

2. MINERALS CONTAINING WATER.

Apophylite (calcium and potassium silicates)—Anal-

cite (calcium and sodium silicates)—Brewsterite (aluminum, barium and strontium silicates)—Chlorite (aluminum, magnesium and iron silicates)—Chonicrite (aluminum, magnesium and calcium silicates)—Gymnite (magnesium silicate)—Harmotome (aluminum and barium silicates)—Heulandite and Stilbite (aluminum and calcium silicates)—Pyrosclerite (aluminum, magnesium, chromium and iron silicates)—Prehnite (aluminum, calcium and iron silicates)—Pectolite (aluminum, calcium and sodium silicates)—Mosandrite (calcium and sodium silicates, containing also iron and titanium)—Chabazite (aluminum, calcium, potassium and sodium silicates.)

Apophylite exfoliates and fuses to a whitish enamel. H=4½ to 5.

Analcite, white or nearly so, fuses to a glass-like mass, colorless. H=5 to 6.

Brewsterite fuses to an opaque white glass.

Chlorite is generally deep green color with pearly lustre; slightly flexible; whitens under the blowpipe and fuses with difficulty to a blackish mass.

Chonicrite. H=2½ to 3. Fuses with intumescence to a whitish glass.

Gymnite fuses on the edges only, becoming opaque. H=2 to 3.

Harmotome fuses without intumescence to a glass. H=4.

Heulandite has a pearly lustre; under the blowpipe exfoliates and fuses to a white enamel.

Stilbite has a vitreous or pearly lustre; under the blowpipe swells up and assumes various forms, finally fusing to an enamel. H=3 or 4.

Pyrosclerite is of a greenish color and fuses to a glass. H=3.

Prehnite; green and with pearly lustre; fuses with intumescence to a vesicular, glassy mass. H=6.

Pectolite; fibrous, white, with silky lustre. H=5; fuses to a white enamel.

Mosandrite is of a brownish or reddish color. H=4; fuses to a brown glass.

Chabazite has a vitreous lustre, and is white or pinkish color; streak white, fuses to an opaque glass.

VIII. THE SUBSTANCE IS INSOLUBLE IN HYDROCHLORIC ACID, AND YIELDS IN THE MICROCOSMIC SALT BEAD A SKELETON OF SILICA.

1. IT IS FUSIBLE BEFORE THE BLOWPIPE.

Amphigene (aluminum and potassium silicates)—Anorthite (aluminum, magnesium, sodium and iron silicates)—Grossulaire (aluminum and calcium silicates)—Keilhauite (titanium, iron, calcium and aluminum silicates)—Knebelite (iron and manganese silicates)—Labradorite (aluminum, calcium and sodium silicates)—Sphene—Titanite (titanium and calcium silicate)—Tachylite (aluminum, calcium, magnesium and sodium silicates)—Wernerite (aluminum, calcium, sodium and iron silicates).

Amphigene gives alumina reaction with cobalt solution; fuses with difficulty.

Anorthite is white and brittle; fuses to a colorless glass.

Grossulaire is a form of garnet; fuses to a brown or black glass.

Keilhauite is of a brown to black color, giving yellow to brown streak; fuses with intumescence to a black glass.

Knebelite fuses to a dull-looking bead which is magnetic.

Labradorite has a pearly lustre. H=6; fuses to a colorless glass.

Sphene or *Titanite* is brown, yellow, or black; streak white; intumesces, and fuses to a dark-colored glass.

Tachylite is black and brittle; fuses to a black glass.

Wernerite is white or whitish and transparent. H=6, fuses to a white glass.

2. INFUSIBLE BEFORE THE BLOWPIPE.

Quartz—Biotite (magnesium and aluminum silicates) Talc (magnesium silicate)—Iolite (magnesium and aluminum silicates)—Hypersthene (magnesium and iron silicates)—Staurolite (aluminum and iron silicates)—Emerald—Euclase (aluminum and glucinum silicates)—Phenacite (glucinum silicate)—Zircon (zirconium silicate)—Topaz (aluminum silicate with aluminum and silicon fluoride)—Uwarowite (aluminum and chromium silicates)—Chlorite (aluminum, iron and magnesium silicates)—Ripidolite (magnesium silicate with magnesium and aluminum oxides)—Opal (silica with water)—Andalusite—Cyanite—Cimolite—Lithomarge—Kaolin and Pyrophyllite (all aluminum silicates).

Decomposed by concentrated sulphuric acid: *Biotite* (magnesia mica) becomes opaque before the blowpipe and fuses only on the edges; gives iron reaction in the borax bead; the wet powder is slightly alkaline; H=2.5.—*Chlorite* exfoliates before the blowpipe, whitens or blackens and

disengages water that has an alkaline reaction.—*Ripidolite*, same as chlorite except that it fuses rather more easily upon the edges.

Minerals possessing a hardness less than 7: *Talc*, becomes red if treated with cobalt solution; exfoliates; is greasy to the touch; H=1.—*Hypersthene* is brown or black; has a metallic lustre on one face; H=6.—*Andalusite* gives alumina reaction with cobalt; is usually translucent.—*Cyanite* whitens before the blowpipe, and then gives the alumina reaction with cobalt solution; flexible; H nearly 7.—*Cimolite* yields water in the glass tube; yields decided blue color with the cobalt solution; has an earthy look.—*Lithomarge* gives up water in the glass tube; exhibits fine blue reaction with cobalt; whitens when alone before the blowpipe; greasy to the touch; streak, greenish white; H=2.5.—*Kaolin* gives off water in the glass tube; affords blue reaction with cobalt; is friable and earthy.—*Pyrophyllite* yields water in the glass tube; exfoliates on the coal and then intumesces considerably, producing white worm-like masses; greenish; H=1.5.—*Opal* yields water in the glass tube; scales off under heating and becomes opaque; H=5.5 to 6.5.

Hardness above 7: *Iolite* is fusible in the slightest degree only; has a vitreous lustre and generally a bluish color.—*Staurolite* is partly decomposed by sulphuric acid; gives in borax bead the reaction for iron; becomes darker colored before the blowpipe.—*Emerald* becomes milky before the blowpipe; at a very high heat, the thin edges become rounded and form a colorless spongy looking scoria.—*Euclase* yields slightly to the blowpipe; whitens and at a very high heat takes on a white enamel.—*Phenacite* is transparent and alterable before the blowpipe.—*Zircon* loses its color (which is from yellow to cinnamon brown) when highly heated; H=7.5.—*Topaz*, the yellow varieties become red if subjected to the blowpipe flame, but

only after cooling; if boric acid be fused on a platinum wire until the green color disappears, and then topaz in powder be added, the green coloration reappears in the flame.—*Andalusite* gives the alumina reaction with cobalt. —*Uwarowite* becomes greenish black before the blowpipe, but becomes lighter green again when cold; gives a green bead with borax;—*Quartz*, vitreous lustre; H=7.

IX. MINERALS WHICH BELONG TO NEITHER OF THE PRECEDING CLASSES.

Tungstite (tungstic oxide)—Scheelite (calcium tungstite)—Cassiterite (tin oxide)—Rutile—Anatase and Brookite (titanium oxides)—Eschynite (titanium, zirconium, calcium and cerium oxides)—Perofskite (calcium titanate)—Pyrochlore (calcium, cerium and niobium oxides with sodium fluoride)—Xenotime (yttrium phosphate)—Spinel (magnesium and aluminum oxides)—Gahnite (zinc, iron and aluminum oxides)—Wolfram (iron and manganese tungstate)—Corundum and Diaspore (aluminum oxides)—Yttrotantalite (tantalum, yttrium and calcium oxides)—Euxenite (titanium, yttrium, uranium and cerium oxides)—Polymignite (titanium, zirconium, yttrium, iron and cerium oxides)—Chrysoberyl (glucinum and aluminum oxides)—Polycrase (niobium, titanium, zirconium, cerium, yttrium and iron oxides)—Klaprothine (magnesium and aluminum phosphates)—Columbite (manganese and iron niobate)—Osiridium—Graphite—Diamond.

The microcosmic salt bead presents the reaction of tungsten; *Tungstite*, soft, has a silky lustre, a yellow color, and blackens before the blowpipe.—*Scheelite* fuses

with difficulty; it is decomposed by hydrochloric acid, leaving a yellow residue; color, white, yellow or brown; streak, white; H=4.5.—*Wolfram* fuses with difficulty to a magnetic globule covered with crystals; dissolves in hydrochloric acid leaving a yellow residue; the borax bead exhibits the manganese reaction; streak brown or black; H=5.5.

The microcosmic salt bead exhibits the titanium reaction; *Anatase*, infusible; color indigo blue to black; streak, gray; H=5.5.—*Rutile*, infusible; brownish red color; yellow streak; H=6.5.—*Brookite*, like anatase; crystallizes in the rhombic system.—*Eschynite*, infusible; intumesces somewhat and turns yellow; streak, yellowish brown;—*Perofskite*, infusible; streak grayish white.

Euxenite, infusible; greasy lustre; dark brown color; streak, brownish red; H=6.5.—*Polymignite*, infusible; metallic lustre; iron black color; dark brown streak; H=6.5.—*Polycrase* decrepitates but is infusible; changes by calcination to a brownish gray mass; is dissolved by sulphuric acid.

Cassiterite gives if heated with sodium carbonate on charcoal little flakes of tin; adamantine lustre; streak clear brown; H=6.5.

Pyrochlore becomes gray before the blowpipe; the borax bead is reddish yellow in the oxidation flame, and deep red in the reduction flame; streak, gray; H=5.5.

Xenotime, infusible; transparent; greasy lustre; brown color; streak varying from yellow to rose color; H=4.5.

Spinel, infusible; crystallizes in regular octohedrons; readily soluble in microcosmic salt bead; H=8.

Gahnite does not dissolve in microcosmic salt; otherwise is like spinel.

Corundum, infusible and insoluble.

Diaspore, infusible; decrepitates violently in the glass

tube, and reduces to little white flakes ; yields water a little below red heat; has a brownish red color; H=5.5.

Yttrotantalite, infusible; gives off water in the glass tube which affords an acid reaction, by reason of the presence of fluohydric acid.

Chrysoberyl, infusible ; insoluble in acids; transparent ; greenish color ; H=8.5.

Klaprothine, infusible; is not attacked by acids unless previously calcined, when it may be to a great extent dissolved; streak white ; H=5.5.

Columbite, infusible ; insoluble in acids ; metallic lustre; streak reddish brown to black; H=6.

Osiridium ; unalterable before the blowpipe ; calcined with nitre in the glass tube it yields the odor characteristic of osmium; H=7.

Graphite burns before the blowpipe ; H=2.

Diamond ; H=10.

APPENDIX.*

(*a.*) *Method of distinguishing the red flame of Lithia from that of Strontia.*—It has been long known that the crimson coloration imparted to the blow-pipe flame by strontia, is destroyed by the presence of baryta. The latter substance, however, as first indicated by the writer, does not affect the crimson flame-coloration produced by lithia. Hence, to distinguish the two flames, the test-substance may be fused with 2 or 3 volumes of chloride of barium, in a loop of platinum wire, the fused mass being kept just within the point or edge of the blue cone. If the original flame-coloration proceeded from strontia (or lime), an impure brownish yellow tinge will be imparted to the flame-border; but if the original red color were caused by lithia, it will not only remain undestroyed, but its intensity will be much increased.

This test may be applied, amongst other bodies, to the natural silicates, *Lepidolite, Spodumene,* &c. It is equally available, also, in the examination of phosphates. The mineral *Tryphylline,* for example, when treated *per se,* imparts a green tint to the point of the flame, owing to the presence of phosphoric acid; but if this mineral be fused (in powder) with chloride of barium, a beautiful crimson coloration in the surrounding flame-border is at once produced.

* The articles in the Appendix from *a* to *i*, inclusive, are taken, with slight alterations, from some published notes of Prof. CHAPMAN, of Toronto. Article *j* originated with Mr. LANDAUER.

(*b.*) *Reaction of Manganese Salts on Baryta.*—When moistened with a solution of any manganese salt, and ignited in an oxidizing flame, baryta and baryta compounds, generally assume, on cooling, a blue or greenish-blue color. This arises from the formation of a manganate of baryta. Strontia and other bodies (apart from the alkalies), when treated in this manner, become brown or dark grey. A mixture of baryta and strontia also assumes an indefinite greyish-brown color. If some oxide of manganese be fused with carbonate of soda, so as to produce a greenish-blue bead, or "turquoise enamel," and some baryta or a baryta salt be melted into this, the color of the bead will remain unchanged; but if strontia be used in place of baryta, a brown or greyish-brown enamel is produced.

NOTE.—Some examples of *Witherite, Barytine,* and *Baryto-calcite,* contain traces of oxide of manganese. These, after strong ignition, often assume *per se* a pale greenish-blue color.

(*c.*) *Detection of Baryta in the presence of Strontia.*—This test is chiefly applicable to the detection of baryta in the natural sulphate of strontia; but it answers equally for the examination of chemical precipitates, &c., in which baryta and strontia may be present together. The test-matter, in fine powder, is to be melted in a platinum spoon, with 3 or 4 volumes of chloride of calcium, and the fused mass treated with boiling water. For this purpose, the spoon may be dropped into a test-tube, or placed (bottom upwards) in a small porcelain capsule. The clear solution, decanted from any residue that may remain, is then to be diluted with 8 or 10 times its volume of water, and tested with a few drops of chromate (or bi-chromate) of potash. A precipitate, or turbidity, indicates the presence of baryta.

(*d.*) *Action of Baryta on Titanic Acid.*—Fused with borax in a reducing flame, titanic acid forms a dark ame-

thystine-blue glass, which becomes light blue and opaque when subjected to the flaming process. The amethystine color arises from the presence of Ti^2O^3: the light-blue enamelled surface from the precipitation of a certain portion of TiO^2. The presence of baryta, even in comparatively small quantity, quite destroys the latter reaction. When exposed to an intermittent flame, the glass (on the addition of baryta) remains dark-blue, no precipitation of titanic acid taking place. Strontia acts in the same manner, but a much larger quantity is required to produce the reaction.

(*e.*) *Detection of Oxide of Manganese when present in minute quantity in mineral bodies.*—The process on page 134 may be varied to advantage, as follows, viz.:—Dissolve the assay in a borax or microcosmic salt bead, and then treat the fused mass with carbonate of soda in excess. If there be a trace of manganese present, the bead will assume the turquoise-enamel appearance, which arises from the formation of manganate of soda.

(*f.*) *Method of distinguishing the Protoxide of Iron* (*FeO*) *from the Sesquioxide* (Fe^2O^3) *in Silicates and other compounds.*—This test serves to indicate, with great certainty, the presence or absence of FeO in bodies generally. It is performed as follows:—A small quantity of black oxide of copper (CuO) is dissolved in a bead of borax on platinum wire, so as to form a glass which exhibits, on cooling, a decided blue color, but which remains transparent. To this, the test-substance in the form of powder is added, and the whole is exposed for a few seconds, or until the test-matter begins to dissolve, to the point of the blue flame. If the substance contain Fe^2O^3 only, the glass, on cooling, will remain transparent, and will exhibit a bluish-green color. On the other hand, if the test-substance contain FeO, this will become at once converted into Fe^2O^3 at the expense of some

of the oxygen of the copper compound; and opaque red streaks and spots of Cu^2O will appear in the glass, as the latter cools.

(*g*.) *Detection of minute traces of Copper in Iron Pyrites and other bodies.*—Although an exceedingly small percentage of copper may be detected in blowpipe experiments, by the reducing process, as well as by the azure-blue coloration of the flame when the test-matter is moistened with chlorhydic acid, these methods fail, in certain extreme cases, to give satisfactory results. It often happens, that veins of iron pyrites lead, at greater depths, to copper pyrites. In this case, according to the experience of the writer, the iron pyrites will, almost invariably, hold minute traces of copper. Hence the desirability, on exploring expeditions more especially, of some ready test, by which, without the necessity of employing acids or other bulky and difficultly portable reagents, these traces of copper may be detected. The following simple method will be found to answer the purpose:—The test-substance, in powder, must first be roasted on charcoal, or, better, on a fragment of porcelain, in order to drive off the sulphur. A small portion of the roasted ore is then to be fused on platinum wire with phosphor-salt; and some bisulphate of potash is to be added to the glass (without this being removed from the wire) in two or three successive portions, or until the glass becomes more or less saturated. This effected, the bead is to be shaken off the platinum loop into a small capsule, and treated with boiling water, by which either the whole or greater part will be dissolved; and the solution is finally to be tested with a small fragment of ferrocyanide of potassium ("yellow prussiate.") If copper be present in more than traces, this reagent, it is well known, will produce a deep-red precipitate. If the copper be present in smaller quantity, that is, in exceedingly

minute traces, the precipitate will be brown or brownish-black; and if copper be entirely absent, the precipitate will be blue or green—assuming, of course, that iron pyrites or some other ferruginous substance is operated upon. In this experiment, the preliminary fusion with phosphor-salt greatly facilitates the after solution of the substance in bisulphate of potash. In some instances, indeed, no solution takes place if this preliminary treatment with phosphor-salt be omitted.

(*h.*) *Detection of Lead in the presence of Bismuth.*—When lead and bismuth are present together, the latter metal may be readily detected by its known reaction with phosphor-salt in a reducing-flame—antimony, if present, being first eliminated; but the presence of lead is less easily ascertained. If the latter metal be present in large quantity, it is true, the metallic globule will be more or less malleable, and the flame-border will assume a clear blue color when made to play upon its surface, or on the sublimate of lead-oxide as produced on charcoal; but in other cases, this reaction becomes exceedingly indefinite. The presence of lead may be detected, however, by the following plan, based on the known reduction and precipitation of salts of bismuth by metallic lead: a method which succeeds perfectly with brittle alloys containing 85-90 per cent. of bismuth. A small crystal or fragment of nitrate of bismuth is placed in a porcelain capsule, and moistened with a few drops of water, the greater part of which is afterwards poured off; and the metallic globule of the mixed metals, as obtained by the blowpipe, having been slightly flattened on the anvil until it begins to crack at the sides, is then placed in the midst of the sub-salt of bismuth formed by the action of the water. In the course of a minute, or even less, according to the amount of lead that may be present, an arbores-

cent crystallization of metallic bismuth will be formed around the globule.

This reaction is not effected by copper; but a precipitation of bismuth would ensue, in the absence of lead, if either zinc or iron were present. These metals, however, may be eliminated from the test-globule, by exposing this on charcoal for some minutes, with a mixture of carb-soda and borax, to a reducing-flame. The zinc becomes volatilized, and the iron is gradually taken up by the borax. If a single operation does not effect this, the globule must be removed from the saturated dark green glass, and treated with further portions of the mixture, until the resulting glass be no longer colored.

(*i.*) *Detection of Antimony in Tube-Sublimates.*—In the examination of mineral bodies for antimony, the test-substance is often roasted in an open tube for the production of a white sublimate. The presence of antimony in this sublimate may be detected by the following process—a method more especially available when the operator has only a portable blowpipe case at his command:—The portion of the tube to which the chief portion of the sublimate is attached is to be cut off by a triangular file, and dropped into a test-tube containing some tartaric acid dissolved in water. This being warmed or gently boiled, a part, at least, of the sublimate will be dissolved. Some bisulphate of potash—either alone, or mixed with some carb-soda and a little borax, the latter to prevent absorption—is then to be fused on charcoal in a reducing-flame; and the alkaline sulphide thus produced is to be removed by the point of the knife-blade, and placed in a small porcelain capsule. The hepatic mass is most easily separated from the charcoal by removing it before it has time to solidify. Some of the tartaric acid solution is then to be dropped upon it, when the well-

known orange-colored precipitate of SbS^3 will at once result.

In performing this test, it is as well to employ a somewhat large fragment of the test-substance, so as to obtain a thick deposit in the tube. It is advisable, also, to hold the tube in not too inclined a position, in order to let but a moderate current of air pass through it; and care must be taken not to expose the sublimate to the action of the flame —otherwise it might be converted almost wholly into a compound of SbO^3 and SbO^5, the greater part of which would remain undissolved in the tartaric acid solution. A sublimate of arsenious acid, treated in this manner, would, of course, yield a yellow precipitate, easily distinguished by its color, however, from the deep orange antimonial sulphide. The crystalline character, etc., of this sublimate, would also effectually prevent any chance of misconception.

(*j.*) *Chlorate of Potassa as a Reagent.*—The action of this salt is, of course, that of energetic oxidation, caused by the evolution of oxygen at a high temperature.

The detection of the oxides of the metals below, is readily effected by the following means:—In a tube 15 centimeters long, and 5 millimeters in diameters, closed at one end, place the test-substance, together with a small quantity of the chlorate; apply heat gradually, at first without, and then with, help of the blowpipe, until no more oxygen is given off. The reaction is then completed, and the color of the test is to be examined.

Flesh color	indicates	presence of	Iron.
Yellowish-brown,	"	"	Lead,
Black, or grayish-black,	"	"	Copper.
Blue to black,	"	"	Cobalt.
Purple,	"	"	Manganese.
Black,	"	"	Nickel.

(*k.*) INDIUM.

This metal was discovered in 1863, by Professor Richter, at Freiburg, Saxony. It is found, in very small quantities, in the black sulphide of zinc of the Freiburg mines.

The metal is nearly the color of aluminum, soft, ductile, and has a specific gravity of 7.14.

OXIDE OF INDIUM

Upon Charcoal.—Under the oxidizing flame becomes, while hot, dark yellow, and upon cooling, light yellow.

Under the reducing flame it is gradually reduced. The reduced metal is volatile, and deposits a coating upon the the coal; the outer flame is, at the same time, tinged with violet.

In Borax Bead.—Under the oxidizing flame, dissolves to a faintly-colored yellow bead, which becomes colorless upon cooling; and if great quantities of the assay be added, becomes opaque.

Under the reducing flame, the glass remains unchanged. If placed upon charcoal, the oxide is reduced—the metal volatilizes, and is again oxidized, and coats the coal. Notwithstanding the presence of soda, the violet color is perceptible in the outer flame.

Treated with Soda.—In the oxidizing flame, insoluble.

In the reducing flame, upon coal, the oxide is reduced; a portion is volatilized, and coats the coal with oxide; and a portion remains in the mass, in small white beads.

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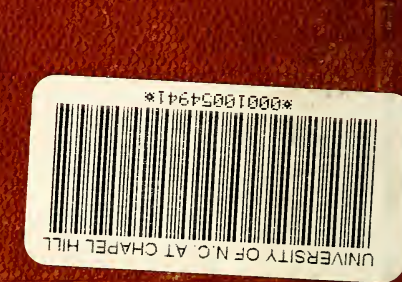
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